THE UNIVERSITY OF ALBERTA

CORRELATION AND CYCLICITY ANALYSIS OF THE JURASSIC-CRETACEOUS KOOTENAY FORMATION NEAR CANMORE, ALBERTA

by

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Abstract

Rocks of the coal-bearing Upper Jurassic to Lower Cretaceous Kootenay Formation were examined at three localities within the Cascade Coal Basin, located 60 miles west of Calgary, Alberta in the southern Canadian Rocky Mountains.

A method for grouping the clastic rocks of the Kootenay utilizing several descriptive and quantitative lithologic parameters and cluster analysis was used to separate hand specimens collected from measured sections in the field into groups or "lithotypes". Three classification levels at which 26, 11 and 6 lithotypes were recognized were derived using this method.

Correlation between a complete section of the Kootenay Formation exposed on Mount Allan and partial sections of the formation exposed on the Three Sisters and Wind Ridge was performed utilizing the technique of cross-association and these lithotypes. Results indicate that the measured section on the Three Sisters best correlates with the lower coal-bearing portion of the Kootenay Formation on Mount Allan, and that the section measured on Wind Ridge best correlates with the uppermost part of the Mount Allan section, and probably includes strata of the overlying Blairmore Group. A separate correlation analysis utilizing cross-correlation of grain size data gave similar results.

The Mount Allan section of the Kootenay Formation was also examined for cyclic repetitions of lithotypes using the techniques of auto-association and substitutability analysis. Results from these analyses indicate the absence of cycles with periods of more than two states. The two-state cycles observed are primarily a result of

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The Mount Allan section of the Kootenay Formation was also examined for cyclic repetitions of lithotypes using the techniques of auto-association and substitutability analysis. Results from these analyses indicate the absence of cycles with periods of more than two states. The two-state cycles observed are primarily a result of

interbedding between fine grained sandstone, siltstone and claystone lithotypes. Deposition of the coal measures of the Kootenay Formation therefore does not appear to have been controlled by a regular succession of environments in the sense of the cyclothemic Carboniferous coal measures of the eastern United States and Great Britain.

Acknowledgments

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Chapter One

INTRODUCTION

Correlation within the coal-bearing late Jurassic to early Lower Cretaceous Kootenay Formation of western Canada is complicated by the lack of suitable index fossils and the lateral variability of the sediments involved. Seam correlations within individual coal areas utilizing rank (Hacquebard and Donaldson, 1972) or pollen and spore variation are of necessity restricted to the lower coal bearing zone of the Kootenay Formation. Regional correlation based on gross lithologic attributes is possible only in a general sense (Jansa, 1972).

The purpose of this study was to examine the lithologic character of the Kootenay Formation at several localities within one coal area, namely the Cascade Coal Basin, to establish correlations within its non-coal-bearing as well as coal-bearing parts. In addition, the formation was examined as a whole for characteristic lithologic cycles which might be of use in correlation and provide an insight into its depositional mechanisms.

The Cascade Coal Basin is located about sixty miles west of Calgary, Alberta between latitudes 50° 50' and 51° 15' North, and longitudes 115° 0' and 115° 20' West (Fig. 1). The Kootenay Formation is exposed within the basin in a northwest-trending band about twenty-five miles long and less than three miles in width. The formation here varies between 3100 and 3800 feet in thickness (MacKay, 1935; Crockford, 1949; and this study). Coal of medium volatile bituminous to semi-anthracite rank has been mined in the basin since the 1880's. The town of Canmore, where the coal mining industry is based, is located near its center (Fig. 1).

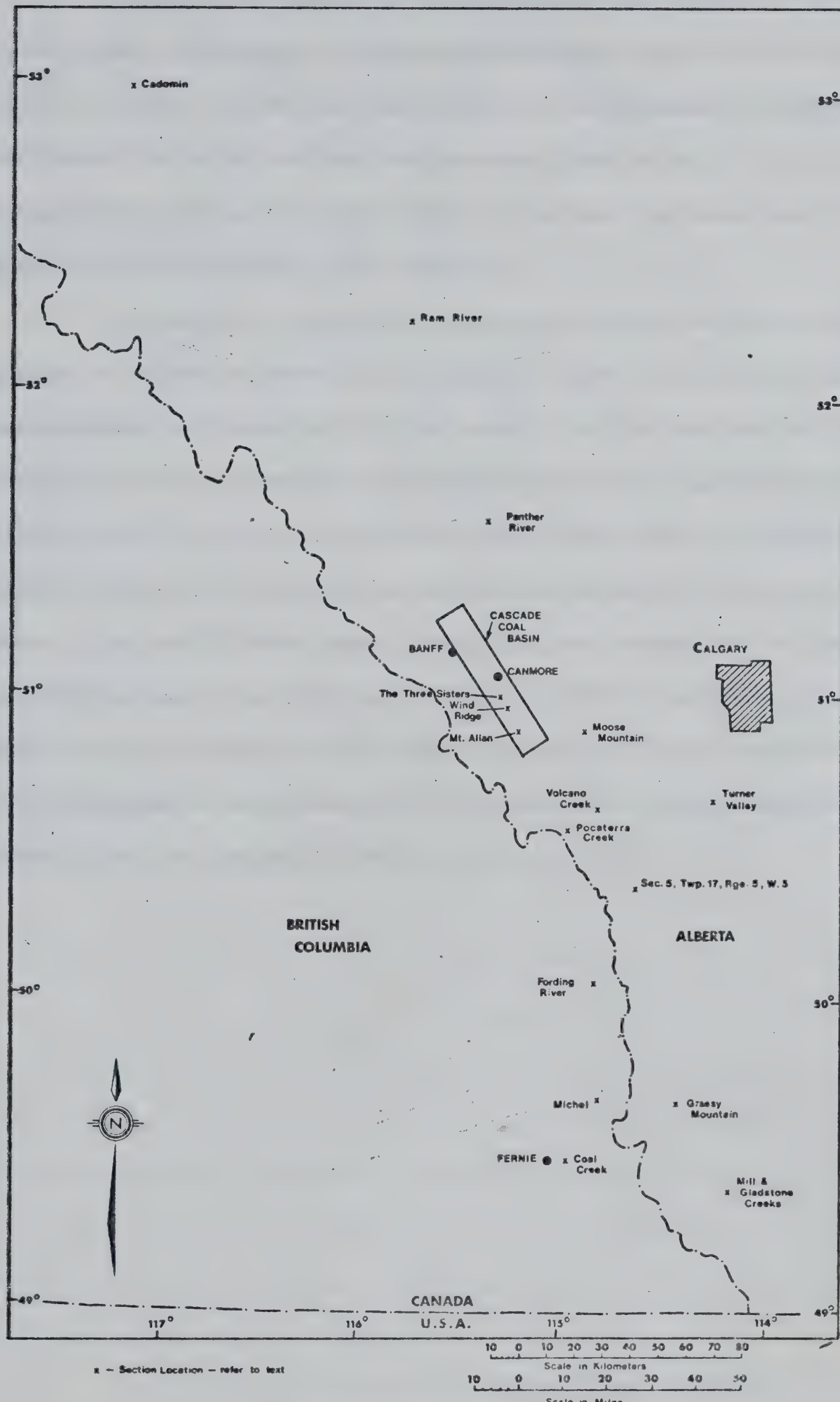


Figure 1 LOCATION of STUDY AREA

Mesozoic sediments in the basin are overridden on the west by Palaeozoic carbonates of the Rundle Mountain thrust sheet (Price, 1970) (Fig. 2). In detail, the geology is complicated by numerous folds and thrust faults of varying displacement, particularly in the area now being mined, and has been the subject of several authors, most notably MacKay (1935) and Norris (1957, 1971).

A complete, relatively undeformed section of the Kootenay Formation exposed on Mount Allan some ten miles southeast of Canmore was measured and described in this study. Partial sections of the formation were measured and described on Wind Ridge and the Three Sisters, six and three and one-half miles respectively southeast of Canmore (Fig. 2). Correlations between these partial sections and the Mount Allan section were established using the techniques of cross-association and cross-correlation (Davis, 1973). The Mount Allan section was also examined for lithologic repetitions or cycles using the techniques of auto-association (Sackin and Merriam, 1969) and substitutability analysis (Davis and Cocke, 1972).

Chapter Two

Regional Stratigraphy and Structure

This chapter describes the stratigraphic and structural aspects of the Kootenay Formation, and, in less detail, the Fernie Formation and Blairmore Group of the southern Canadian Rocky Mountains, and thus is primarily a literature review.

I. Stratigraphy

The late Jurassic to early Lower Cretaceous Kootenay Formation is overlain, in part unconformably, by conglomerates, sandstones and mudstones of the Cretaceous Blairmore Group and overlies, with local disconformity, the marine shales of the Jurassic Fernie Formation.

A. The Fernie Formation

Strata of the Fernie Formation are present in a region about 700 miles long and 80 miles wide extending from the International Boundary in southwest Alberta to the Peace River area of British Columbia. Within the Cascade Coal basin the average thickness is about 1100 feet (Crockford, 1949).

Abundant ammonite remains within the Fernie Formation indicate a Sinemurian to Portlandian (Jurassic) age (Frebold, 1957).

The dominant lithology within the Fernie is dark marine shale, interbedded with minor fine-grained sandstone, which becomes progressively more abundant towards the upper gradational contact with the overlying Kootenay Formation. The Fernie Formation commonly lies with regional disconformity on the Triassic Spray River Formation or on Palaeozoic strata. Table 1 provides a generalized lithostratigraphic zonation of the Fernie Formation.

In the Cascade Coal Basin, as elsewhere, the Fernie is poorly

Unit Name	Stage	Lithology and Thickness
Passage Beds	Oxfordian-Portlandian	Dark shales interbedded with sandstones; sandstones become more numerous towards the top. Generally less than 400 feet thick.
Green Beds	Lower Oxfordian	Glauconitic sandstones and shales in the south, dark shales with concretions further north. Generally less than 250 feet thick.
Grey Beds	Callovian	Mainly grey shales with minor sandstones. Generally less than 250 feet thick.
Rock Creek Member	Middle Bajocian	Mainly dark shales with sandstone; abundant Belemnites. Generally less than 50 feet thick.
Paper Shale	Toarcian	Mainly dark, thin bedded papery shales with minor sandstone and conglomerate at base in some localities. Usually about 100 feet thick.
Nordegg Member	Sinemurian	Dark indurated phosphatic shales to cherty and phosphatic sandstones and limestones. Generally less than 150 feet thick.

Table 1. Generalized Lithostratigraphic Zonation of the Fernie Formation (after Frebold, 1957 and Frebold et al., 1959)

exposed owing to its recessive nature. Only the upper sandstones, or "Passage Beds" (Table 1) were observed on Mount Allan. As the Fernie-Kootenay contact is gradational in nature, the determination of its position is somewhat arbitrary. On Mount Allan, it was placed at the base of a resistant, thick-bedded, fine to medium-grained, cross-laminated sandstone unit 49.3 feet thick. The quartzose sandstones of the upper Fernie immediately below the contact tend to be thinner bedded, slightly calcareous, and less resistant than those of the Kootenay above, and also exhibit a parting nearly perpendicular to bedding planes. Allan and Carr (1947) noted a similar parting within the upper Fernie sandstones of the Highwood-Elbow area immediately to the south of Mount Allan. Here these authors put the contact at an irregular bed of "...soft iron-stained shale less than one inch thick" (p. 22). On the basis of this irregularity, they suggested post-Fernie erosion, however there is no fossil (Frebold, 1957) or lithologic evidence to support this in the Mount Allan area.

B. The Kootenay Formation

1. General

The Kootenay Formation is present in a region that extends from the International Boundary in southwest Alberta, to the headwaters of the Red Deer River. In gross form, it is a northeast-thinning clastic wedge, which has been interpreted by Jansa (1972), among others, to be the result of deposition within a late Jurassic to early Cretaceous northeasterly-prograding delta system.

Kootenay strata attain a maximum thickness within the Fernie Basin of 3600 feet at Michel (MacKay, 1933). To the east, at Grassy Mountain, a distance palinspastically of about 100 miles (Norris, 1971),

it is 413 feet thick (Norris, 1959). Farther north, at the latitude of Banff, it is only 280 feet thick at Moose Mountain (Beach, 1943) whereas at Mount Allan to the west, it is 3800 feet thick.

Thinning of the Kootenay to the northeast may be attributed to two causes:

a) Sedimentary thinning as a result of decreasing supply of sediment with increasing distance from the source, or

b) Erosional removal of beds towards the northeast during development of the pre-Blairmore unconformity.

It seems probable that (b) accounts for most of the observed thinning, as lower Kootenay strata are almost universally present wherever the formation is found, whereas, progressively more upper Kootenay strata are missing towards the northeast. This conclusion is supported by the nature of the Blairmore-Kootenay contact, which ranges from essentially conformable in the southwest, as in the Fernie Basin (Newmarch, 1953), to markedly unconformable in the northeast, as at Moose Mountain (Beach, 1943). However both erosional removal and thinning of individual units within the formation to the northeast were observed by Allan and Carr (1947) in the Highwood-Elbow area.

2. Lithostratigraphy and Nomenclature

Sediments of the Kootenay generally become coarser to the west, and more calcareous and coarser towards the top. Coal seams decrease in thickness, lateral continuity and frequency upwards above the Moose Mountain Member. Almost everywhere the base of the formation is marked by a persistent, resistant sandstone unit. In localities where there has been little pre-Blairmore erosion of Kootenay strata, four gross lithologic units may be recognized (from base):

a) A resistant, quartzose sandstone unit ranging from 20 to 235 feet in thickness.

b) A recessive shale, sandstone and coal-bearing unit usually between 400 and 1700 feet in thickness.

c) A unit of interbedded sandstone, siltstone, mudstone and minor coal which becomes coarser near the top and is usually between 500 and 1500 feet in thickness.

d) An upper unit of interbedded conglomerate, sandstone and mudstone usually between 300 and 1700 feet in thickness.

Several, mostly informal subdivisions of the formation have been suggested (Allan and Carr, 1947; Newmarch, 1953; Norris, 1959; Jansa, 1972) and are summarized in Figure 3.

Norris (1959) proposed a type section for the Kootenay at Grassy Mountain in southwestern Alberta, where the formation is 413 feet thick, and recognized four members; the Moose Mountain, Adanac, Hillcrest and Mutz in ascending order. The Moose Mountain Member is equivalent to the widespread basal Kootenay sandstone. The Adanac, Hillcrest and Mutz Members are equivalent to the lower part of the coal-bearing unit (unit b above), as the uppermost units (units c & d above) have been removed by pre-Blairmore erosion at this locality (Pocock, 1964).

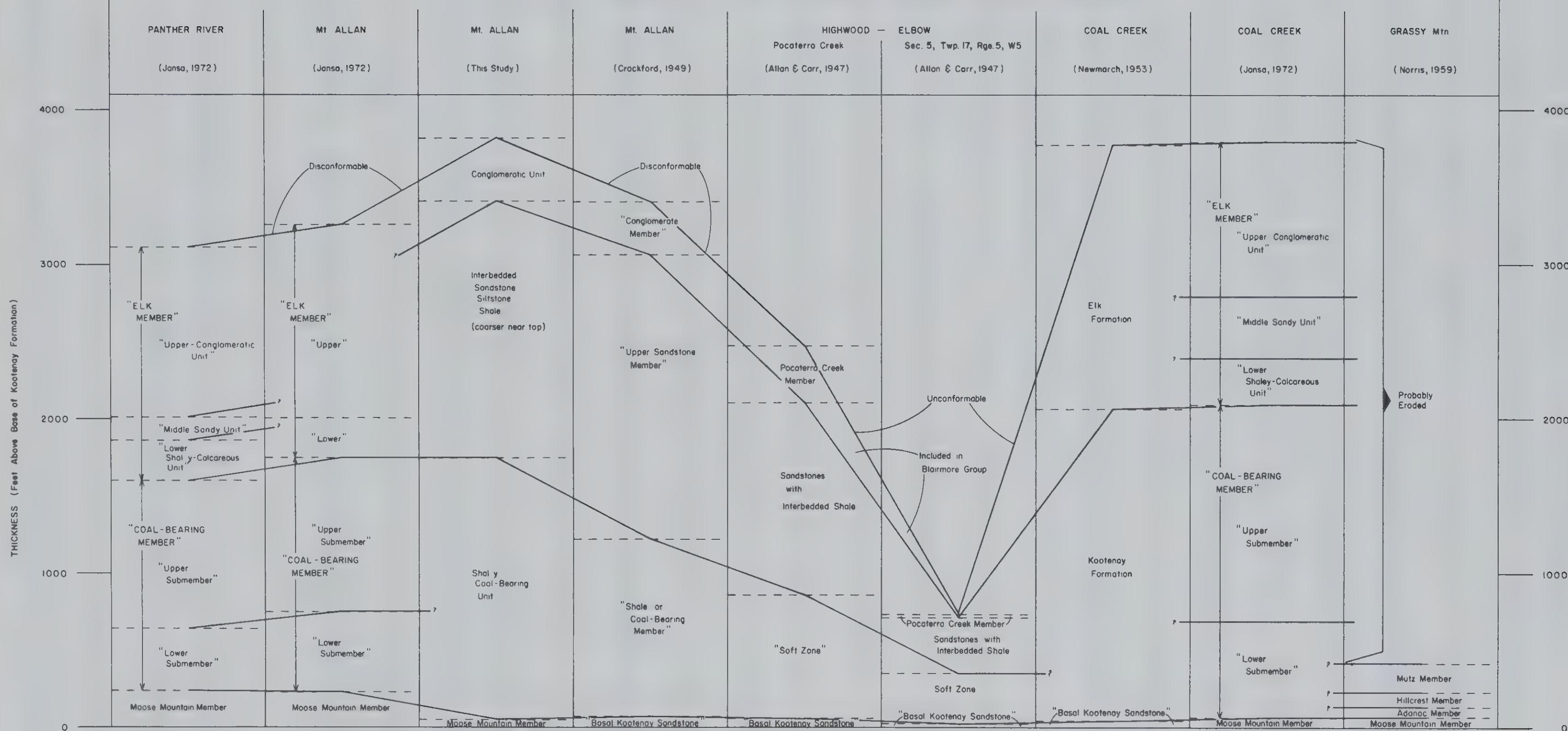
To the north, at Mount Allan, where an essentially complete section of the Kootenay is exposed, Crockford (1949) recognized four units (from base):

a) A "basal sandstone member", 68 feet thick.

b) A "shale and coal-bearing member", 1147 feet thick.

c) An "upper sandstone member", 1539 feet thick.

FIGURE 3 LITHOSTRATIGRAPHIC NOMENCLATURE of the KOOTENAY FORMATION SHOWING MOST PROBABLE CORRELATIONS



d) A "conglomerate member", 346 feet thick.

In the Fernie Basin, Newmarch (1953) termed the lithologic equivalent to Crockford's "conglomeratic member" the Elk Formation, and placed the upper boundary of the Kootenay just above the highest occurrence of commercial coal seams. In the Highwood-Elbow area, Allan and Carr (1947) had called Crockford's "conglomeratic member" the Pocaterra Creek Member and assigned it to the Blairmore Group (Fig. 3).

Jansa (1972) recognized six units in the Kootenay Formation of the Panther River area, based primarily on a detailed environmental analysis. He termed the basal sandstone the Moose Mountain Member (after Beach, 1943 and Norris, 1959), subdivided the coal-bearing strata into upper and lower submembers on the thickness and spacing of coal seams, and termed the remainder of the formation the Elk Member, which he further subdivided into a "lower shaly-calcareous unit", a "middle sandy unit" and an "upper conglomeratic unit". He correlated his Elk Member with the Elk Formation of Newmarch (1953) in the Fernie Basin and suggested that the three submembers he recognized are also present in the Fernie area. A study of the published section of Newmarch (1953) indicates that this is not the case as conglomerate beds are found throughout Newmarch's Elk Formation, and thus the lower two units of the Elk Member as noted by Jansa are either not recognizable as such in the Fernie area, or are to be found within what he termed the "upper coal-bearing submember" there.

It is apparent from this profusion of names that although approximate correlations are possible between areas separated by several tens of miles, the correlation of small segments of Kootenay strata between such areas is likely to be obscurred by lithostrati-

graphic variations which are to be expected from the nature of the strata involved.

3. Age

The discovery of the ammonite Titanites occidentalis by Newmarch (1953) in the basal Kootenay sandstone of the Fernie Basin, led Frebold (1953) to assign a late Portlandian age to this stratum. Jansa (1972) (on the basis of biostratigraphic data contained in an unpublished report by Chamney (1959)) suggested that this unit is time-transgressive and ranges in age from late Portlandian in the Fernie Basin and at Mount Allan, to middle Oxfordian on Volcano Creek south of Moose Mountain (Fig. 1), and postulated a late Jurassic depocenter in the Volcano Creek area on this evidence.

From studies of floral assemblages in the Fernie Basin, Bell (1955) suggested a Barremian age for strata of the Kootenay and Elk Formations of Newmarch (1953). Pocock (1962) reported a late Barremian flora from equivalents of the overlying basal Blairmore conglomerate, and in 1964 concluded that the entire Kootenay at its type section on Grassy Mountain is contained within the late Jurassic Portlandian to Purbeckian stages.

We may conclude therefore, that where Kootenay strata are relatively unaffected by pre-Blairmore erosion, they span middle Oxfordian to Barremian time at a maximum, and that in most such areas, the time span may be restricted to late Portlandian to Barremian.

4. Area of Provenance

Sediment transport within the Kootenay is generally from the southwest towards the northeast (Rapson, 1965; Jansa, 1972), with a transport distance of approximately 150 miles based on textural

considerations (Jansa, 1971).

Clastic components from the upper Kootenay and lower Blairmore have been genetically classified by Rapson (1965) into metamorphic, pyroclastic, stable detrital and phosphorite-bitumen-carbonate suites, each with its distinct source area. She suggested that the metamorphic suite was derived from the Shuswap metamorphic complex, the pyroclastic suite from the Pennsylvanian volcanic province, the stable detrital suite from a reworked Palaeozoic or pre-Palaeozoic source, and the phosphorite-bitumen-carbonate suite from the late Palaeozoic and early Mesozoic sedimentary succession.

5. Correlatives

North of the headwaters of Red Deer River, Kootenay strata pass into the non-coal-bearing Nikanassin Formation, and south of the International Boundary they possibly correlate with the lowermost Kootenay Formation. To the east, beneath the Alberta plains, the formation has been removed by pre-Blairmore erosion.

C. The Blairmore Group

The late Lower Cretaceous Blairmore Group is confined to the Rocky Mountain Foothills and Front Ranges of Alberta and British Columbia.

Blairmore strata are recognized from the International Boundary to as far north as the Athabasca and Smoky Rivers, and correlate with thinner marine and non marine Lower Cretaceous sediments of the Mannville and basal Colorado Groups east of the Foothills in the subsurface of the Alberta plains. The group lies with regional unconformity on Kootenay strata in the south and on Nikanassin strata north of Red Deer River. As mentioned previously, the period of non-

deposition represented by this unconformity increases eastward. As with the Kootenay Formation, sediments of the Blairmore Group become coarser and thicker westward. The group attains a maximum thickness of 6500 feet in the Fernie Basin of British Columbia (Price, 1962). The transport direction of the clastic components of Blairmore sediments is from west to east and northeast with an inferred source area in the western ranges of Rocky Mountains and the Purcell and Selkirk Mountains (Mellon, 1967).

Mellon (1967) has recently defined a type section for the Blairmore Group on Mill and Gladstone Creeks in the Crowsnest Pass. He recognized three formations based on lithologic and palynologic variations (from base):

1. Gladstone Formation, consisting of a basal cherty quartzose sandstone and conglomerate unit 43 feet thick; a middle shaly, silty and fine grained sandstone unit 173.4 feet thick and an upper fossiliferous "calcareous" unit of dark grey calcareous shale and silty fresh water limestone 35.3 feet thick.
2. Beaver Mines Formation, consisting of non-marine varicoloured shale, green sandstone and igneous pebble conglomerate 935.1 feet thick.
3. Mill Creek Formation, consisting of a basal sedimentary succession of quartzose cherty sandstones and varicoloured shales 226.1 feet thick and an upper succession of pyroclastic beds 345 feet thick termed the "Crowsnest Member" by Mellon and mapped as the "Crowsnest Volcanics" or the "Crowsnest Formation" by previous workers.

Sandstones of the Gladstone and Mill Creek Formations contain abundant siliceous sedimentary or metasedimentary detritus, whereas sandstones of the Beaver Mines Formation contain abundant volcanic detritus. Both the Gladstone and Beaver Mines Formations contain mainly non-dicotyledonous flora whereas the Mill Creek Formation contains predominantly dicotyledonous forms. This abrupt change in sandstone composition and flora indicates a prominent pre-Mill Creek period of non-deposition within the Blairmore Group (Mellon, 1967).

North of latitude 50° North, the Crowsnest Member of the Mill Creek Formation is absent and north of about latitude 51° 30' North, this formation is absent altogether.

Blairmore strata contain commercial coal seams north of Red Deer River. Workers prior to Mellon (1967) mapped three formations within the group (from base):

1. Cadomin Formation; 20 to 100 feet of chert and quartzite-pebble conglomerate and quartzose sandstones.
2. Luscar Formation; interbedded sandstone, siltstone, mudstone and coal, about 900 feet thick at the latitude of Ram River.
3. Mountain Park Formation; green or greenish grey sandstones, siltstones and mudstones, about 300 feet thick in the Ram River area and up to 1000 feet thick in the Cadomin area.

Mellon (1967) suggested that lithologic differences between sandstones of his Gladstone and Beaver Mines Formations noted in southern Alberta are also present in the central and northern Foothills, and that the Cadomin and basal non-coal-bearing portion of the Luscar Formation correlate with his Gladstone Formation, and that the upper, coal-bearing

part of the Luscar and the Mountain Park Formations correlate with his Beaver Mines Formation.

Floral and microfaunal evidence suggest a late Barremian (Pocock, 1964) to late Albian or possibly early Cenomanian age for the Blairmore Group (Mellon, 1967).

On Mount Allan, Blairmore strata are represented by about 1000 feet of conglomerates, sandstones and mudstones at the base of the group preserved in the core of the Mount Allan Syncline. The remaining Blairmore strata, which Crockford (1949) suggested may have reached a total thickness of 3300 to 6500 feet, have been removed by erosion.

D. Depositional Environment of the Jurassic-Lower Cretaceous Succession

The most detailed environmental model proposed to date for the Kootenay and its bounding strata is that of Jansa (1972). He postulated two late Jurassic to early Cretaceous depocenters, one in the Volcano Creek area, and one in the Crowsnest Pass region, and attributed Fernie, Kootenay and Blairmore deposition to a northeasterly-prograding delta system. The upper Fernie "Passage Beds" represent the prodelta facies of his model; the basal Kootenay sandstone represents delta front (strand-plain) sandsheets; the coal-bearing member represents deposition first on a lower, then an upper deltaic plain; and the Elk Member and basal Blairmore Group represent deposition on an alluvial plain, mainly by braided streams. Jansa supported his interpretation with lithologic, sedimentologic and paleontologic data, and his conclusions agree with other less detailed environmental studies made by earlier authors (Rapson, 1964; Crockford, 1949).

The mode of occurrence of coal seams is of special significance in Jansa's (1972) model. Jansa considered seams of the lower part

of the coal-bearing member, which are more continuous and of greater economic import than those of the upper, to be related to periodic destructional-constructional phases in delta development as a result of relative sea level fluctuations, producing either short lived marine transgressions and associated landward migrations of coastal flora, or regressions and seaward migration of coastal flora. Seams in the lower submember which are less continuous laterally may be the result of organic acculations in marshes of interdistributary basins or chenier plains, where their continuity was broken by distributaries and beach ridges. He suggests that seams of the upper coal-bearing member are the result of deposition further from the coast on an upper deltaic plain, and are of two types:

1. Thin, lensoid seams interpreted as being the result of accumulation in upper deltaic-alluvial plain marshes.
2. Elongate, lenticular seams interpreted as being the result of the allochthonous accumulation of organic debris in "oxbow lake"-type settings.

The reader is referred to Jansa's (1972) paper for a more detailed account of his depositional model.

II. Structure

Sediments of the Kootenay and Fernie Formations and Blairmore Group are exposed mainly in the eastern deformed belt of the southern Canadian Rocky Mountains. Major displacement along southwest-dipping imbricate thrust faults during the late Cretaceous to early Tertiary Rocky Mountain Orogeny, has resulted in segmenting the Proterozoic to Mesozoic sedimentary sequence into individual thrust plates. Large-scale folding was also an important mechanism of deformation during

this orogeny, particularly within less competent units, and is often confined to individual thrust plates. As a result of orogenic compression, original depositional distances have been attenuated in a southwest to northwest direction by up to forty percent (Price and Mountjoy, 1970), and strata have been transported northeastward from their sites of deposition.

Folds are often assymetric and overturned to the northeast in the Front Ranges and Foothills. Strata commonly dip to the southwest at somewhat shallower angles than thrust faults. The coal seams of the Kootenay Formation are often the loci of thrust movements and disharmonic folds because of their extremely incompetent nature.

Chapter Three

Data Collection and Section Locations

The majority of work during the 1972 field season was concentrated on the southeastern half of the Cascade Coal Basin, where the Kootenay Formation is most completely exposed. Three major sections of Kootenay strata were examined, and the purpose of this chapter is to describe the methodology used in data collection and the location, access and structural conditions associated with each section.

I. Data Collection

Descriptions of measured sections were recorded by several methods:

a) A standard data sheet (Fig. 4) was used for each lithologic unit described in the field. On these sheets, unit thickness, attitude, major and minor lithologies, bed thickness, sedimentary structures, sampling sequence, structural complications, and lithologic paramcters such as grain size, color etc., were noted.

b) Verbal descriptions of units were made using a portable cassette tape recorder and later transcribed to supplement information from the data sheets.

c) Each unit described in the field was photographed and sampled at five foot intervals and at every lithology change.

A total of 1290 samples were collected in the field; these were all slabbed and examined under a binocular microscope. Thin sections were cut from 163 representative samples, and used in conjunction with the binocular microscope examination to aid in the deter-

Figure 4 - Field Data Description Sheet

UNIT DATA SHEET

STATION NUMBER

Year	Project	Serial No.	UTM Zone	UTM Northing	UTM Easting	Card Type
1 2	3 4 5	6 7 8	9 10	11 12 13 14 15 16 17	18 19 20 21 22 23	24 25

ELEV________ AIR PHOTO____________

A BASIC PLOTTING DATA

DIP________ DIP DIR________

WAY UP: NRML OVRD IDRM

UNIT THICKNESS ____________

TYPE OF OUTCROP

O/C SUB O/C TRENCH

EXTENT OF UNIT____________

B MAJOR LITHOLOGY

% OF UNIT ________

TYPE	MDFR	SIZE	SORT	CLUR
		VF		WTHR
SHLE	SHLY	F		
SLST	SLTY	M		
SDST	SNDY	CRS		
CNGL	PBBL	VCR		FRSH
CARB	CALC	PBBL	POOR	
COAL	COAL	CBBL	MODR	
		BLDR	WELL	

COMPONENTS-BREAKDOWN BY PERCENT

	PERCENT CLASTS	PERCENT MATRIX CLAY	SAND	SILT	PERCENT CEMENT	TOTAL % 100
QTZ						
CO_3						
CHRT						
FLDP						
RKFM						
FRAG						
OTHR						
SAMPLE						

C MINOR LITHOLOGY

LTLG	%	DISTRIBUTION Top Bottom Middle Disper.	GRAIN SIZE				COLOUR Fresh Weathered
SILTY							
SHALE			VF	F	M	CR	
SANDY							
SLST			VF	F	M	CR	
SDST			VF	F	M	CR	
CNGL			VF	F	M	CR	
COAL			VF	F	M	CR	
CARB			VF	F	M	CR	

D SEDIMENTARY FEATURES

1. NATURE OF CONTACT:
   GRADATIONAL SHARP
   CONFORM. UNCONFORM.
2. BEDS: IN INCHES

THLM	LAMN	VTBD	THBD	MDBD	TKBD	VTKB
<.1	.1-.4	.4-1	1-4	4-12	12-36	>36

   WTHR: RECESSIVE MODERATE RESIST.
   WYUP: NRML OVRD IDRM
3. STRUCTURES
   BEDS: X GRDD CNTD
   CAST:
   RPMK:
   OTHR:
4. POROSITY - PERCENT
   <3 3-10 10-20 >20
5. FOSSILS: YES NO
   TYPE:
   SMPL:

E STRUCTURES

1. JOINTS: YES NO MESO

	OPEN	CLSD	VEINED
CLASS			
No. SETS			
SPACING			

2. CLEAVAGE: YES NO MESO
   TRND________ PLNG________
3. FOLDS SYMMETRY SMCL
   AMCL S Z (VIEW NW)
   YES
   NO VERGENCE
   MESO INTENSITY LOW MDRT SVR
4. FAULTS

	EXNS	CNCR	OTHER	
PRSN				
TRND				
PLNG				
SCKD				
SENSE				
MESO				

PHOTOS:

Quant	From Roll	From Frame	To Roll	To Frame

DIAGRAMS & REMARKS

(LABEL ALL DIAGRAMS)

	ORND	NRND
SMPL	____	____
MESO	YES	NO
NOTES	YES	NO

DATE____________

mination of mineralogic composition.

The following variables were estimated, where possible, for each sample:

i) mean grain size

ii) range of grain size

iii) % of clasts

iv) % of matrix

v) % of cement

vi) % of black chert

vii) % of grey chert

viii) % of brown chert

ix) % of green chert

x) % of white chert

xi) % of black quartzite

xii) % of grey quartzite

xiii) % of green quartzite

xiv) % of brown quartzite

xv) % of white quartzite

xvi) % of rock fragments

xvii) % of clastic carbonate (both calcite and dolomite)

xviii) % of carbonaceous material

xix) % of quartz

xx) presence or absence of laminations and scale

xxi) presence or absence of cross-laminae

xxii) presence or absence of soft sediment deformation and degree

xxiii) presence or absence of carbonaceous partings

xxiv) presence or absence of graded bedding and scale

xxv) presence or absence of symmetric, assymetric or climbing ripple traces

xxvi) fresh and weathering color

xxvii) presence or absence of plant remains

xxviii) whether calcareous and degree

xxix) sorting

xxx) roundness of grains

Similarity coefficients, based on the values of these variables, were calculated between each pair of samples by the method discussed in chapter 4. These coefficients were then used to separate samples into distinct groups which were in turn used in correlation and cyclicity analysis as described in chapters 5 and 6.

II. Section Location and Access

A. Mount Allan Section

1. Location

The Kootenay Formation is well exposed on the northeast face of Mount Allan at the southeastern end of the Cascade Coal Basin in Secs. 21 and 28, Twp. 23, Rge. 9 W5. Two major thrust faults of small but indeterminate displacement are present in the section where measured. One lies about 200 feet below the Kootenay-Blairmore contact, dips southwest and causes a repetition of about 75 feet of strata; the other also southwest-dipping, occurs about 1500 feet above the base of the formation, and causes repetition of about 30 feet of strata. Dips of beds in the measured section on Mount Allan, which lies in the eastern limb of the Mount Allan Syncline, are southwesterly at 25 to 35 degrees.

The Kootenay Formation on Mount Allan was first measured and described by Crockford (1949). Later, the Kootenay-Blairmore contact

was the subject of a detailed petrographic analysis by Rapson (1964, 1965). The lowermost 1500 feet of the Kootenay Formation examined in this study were measured and described about one half mile northwest of Crockford's (1949) section; the upper 1500 feet were measured at approximately the same location as Rapson's (1965) ridge section and Crockford's section.

In all, 4032 feet of strata were measured on Mount Allan, including 209 feet of Blairmore, 3808 feet of Kootenay and 25 feet of the uppermost Fernie Formation. The section was measured in three segments. The first begins about 250 feet above the Kootenay-Blairmore contact, three-quarters of a mile northeast of the summit of Mount Allan at an elevation of 8900 feet a.s.l., and ends at the base of a conglomerate bed in the hanging wall of the first thrust mentioned above. A total of 605 feet of Kootenay and Blairmore strata were measured in this segment (segment 1 on geologic map Fig. 2). The second part of the section begins at the base of the conglomerate bed mentioned above in the footwall of the first thrust just below a secondary peak on the northwest face of Mount Allan, and ends at tree-line, just above the second thrust noted above. It encompasses 1900 feet of Kootenay strata (segment 2 on geologic map Fig. 2). The lowermost bed in segment 2, a resistant sandstone unit, was followed northwest for about three-quarters of a mile along the northeast slope of Mount Allan to an area of more favorable exposure, the start of segment 3, which includes the lowermost 1500 feet of Kootenay strata and the uppermost 25 feet of the Fernie Passage-beds (segment 3 on geologic map Fig. 2).

Approximate UTM coordinates of the start and finish of each

section are given in Table 2.

2. Access

Access to segments 1 and 2 of the Mount Allan section is by a private road through the Marmot Creek watershed study area from the Ribbon Creek turnoff on the Kananaskis Forestry Trunk Road, and then by foot up the northeast face of Mount Allan.

Access to the lowermost part of the section is by a road belonging to The Canmore Mines Ltd., which begins near the Pigeon Mountain turnoff on the Trans-Canada highway and ends at treeline on Mount Allan in the northeast corner of Sec. 29, Twp. 23, Rge. 9, W5. From here, the start of segment 3 is reached by foot along the northeast face of Mount Allan.

B. Wind Ridge Section

1. Location

The upper part of the Kootenay Formation is well exposed on Wind Ridge about 5 miles northwest of Mount Allan in Sec. 2, Twp. 24, Rge. 10 W5. Five hundred feet of uppermost Kootenay and possible lower Blairmore strata were measured, beginning at a geodesic survey marker at the summit of Wind Ridge (7100 a.s.l.) and extending down the southeast slope to about 6500 feet a.s.l. Approximate UTM coordinates of the start and finish of the Wind Ridge section are given in Table 3.

Strata on Wind Ridge, are unfaulted and essentially flat lying to gently southwest-dipping ($2^{\circ} - 10^{\circ}$). The axis of the Mount Allan Syncline cuts Wind Ridge about one-quarter mile southwest of the section location, and west of this beds are near vertical or overturned to the northeast.

Strata on Wind Ridge consist of conglomerate interbedded

Table 2

UTM coordinates of the Mount Allan Section
(Grid Zone 110)

Segment		Elev. (feet a.s.l.)	Northing ($x10^3$m.)	Easting ($x10^3$m.)	Thickness Blairmore	Thickness Kootenay	Thickness Fernie
1	Start	9000	5647.4	626.1	209'	400'	-
	End	8600	5647.7	626.15			
2	Start	9000	5648.0	626.45	-	1900'	-
	End	7500	5648.45	627.0			
3	Start	7900	5649.3	626.0	-	1500'	25'
	End	6700	5649.9	626.35			

Table 3

UTM Coordinates of the Wind Ridge and Three Sisters Sections
(Grid Zone 110)

Section	Elev. (feet a.s.l.)	Northing ($x10^3$m.)	Easting ($x10^3$m.)	Thickness of strata measured (ft.)
Wind Ridge				
Start	7100	5653.3	619.8	500'
End	6500	5653.0	619.8	
Three Sisters				
Start	6800	5654.8	617.15	282'
End	6600	5655.2	617.4	

with sandstone, overlying a less resistant sequence of mudstone, siltstone and sandstone. The conglomerates may belong to either the basal Blairmore or the Kootenay, and one of the objectives of this study was to determine the best possible correlation with conglomerates on Mount Allan.

2. Access

Wind Ridge may be approached either from the southeast or the northwest on roads owned by The Canmore Mines Ltd. From the northwest the road follows Stewart Creek to the eastern part of Sec. 10, Twp. 24, Rge. 10, W5, from whence the summit, to the southeast, may be reached by foot. From the southeast one can drive to the northwest corner of Sec. 1, Twp. 24, Rge. 10 W5 and from there hike due west to the summit.

C. Three Sisters Section

1. Location

A section of lower Kootenay strata was measured in the extreme southwest corner of Sec. 10, Twp. 24, Rge. 10 W5, on a northeast-facing slope east of the Three Sisters. At this location, strata are overturned and dip southwest at 40 to 50 degrees.

The section begins at the Rundle fault, which thrusts Mississippian limestones over the Kootenay, and ends about 600 feet to the northeast. Approximate UTM coordinates for the Three Sisters section are given in Table 3.

2. Access

Access to the Three Sisters section is on a road owned by The Canmore Mines Ltd. which follows Three Sisters Creek to the center of Sec. 16, Twp. 24, Rge. 10 W5, and from there by foot southeast to the start of the section.

Chapter Four

Classification of Samples

Computer techniques were used to separate samples into relatively homogenous groups. To do this, data collected in the initial sample examination were coded in the manner described below, and Jaccard's similarity coefficients calculated between all pairs of samples. These coefficients were arranged in an n x n lower triangular matrix, (where n equals the number of samples), and entered into the cluster analysis, "Dendrograph" Fortran lV program documented by McCammon and Weninger (1970). This program employs an unweighted pair-group method of cluster analysis and provides as output a "dendrograph" which illustrates groupings within the samples. Using the dendrograph, samples can be separated into a maximum of n groups (each sample being defined as one group), which may then be combined in the manner evident from the dendrograph into as few as one group. Thus, the resultant subdivision scheme can be as detailed or as simple as one desires.

Initially, all 1290 samples collected in this study were to be entered into the Dendrograph program at one time. The memory size of the IBM 360/67 computer used was too small to manipulate such a large matrix, however, and it was necessary to arbitrarily separate samples into smaller, more manageable groups. Thus the following five groups were established according to the mean grain size of samples:

1. claystone and coal - clay sized clasts (less than 1/256 mm.)
2. siltstone - silt sized clasts (1/256 mm. to 1/16 mm.)
3. fine grained sandstone - very fine to fine sand sized clasts (1/16 mm. to 1/4 mm.).
4. coarse grained sandstone - medium to very coarse sand sized clasts (1/4 mm. to 2 mm.).

5. conglomerate - pebble sized clasts (greater than 2 mm.).

Samples in each of these groups were then separated using the Dendrograph program into smaller subgroups henceforth referred to as "lithotypes". These lithotypes were used for correlation and the cyclicity analysis as discussed in chapters 5 and 6 respectively.

Twenty-six lithotypes were initially differentiated in this study. These were then combined to form subdivision levels at which 11 and 6 lithotypes were recognized, realizing that a significant correlation or cycle may be masked by a too detailed subdivision scheme (Davis and Cocke, 1972). Most quantitative studies of cyclical successions to date have differentiated fewer than ten lithotypes for this reason (Krumbein, 1967; Schwarzacher, 1969; Read and Merriam, 1970). Correlation and cyclicity analysis techniques were performed at each of these subdivision levels.

I. Weighting Variables and Coding Data

Data for samples in this study fall into the following four categories recognized by Wishart (1969):

1. Numeric or quantitative data - data measured on interval and ratio scales, eg. mineralogic composition.
2. Ordered multistate or semi-quantitative data - data measured on ordinal scales, eg. sorting.
3. Unordered multistate data - nominal data with several mutually exclusive categories, eg. color.
4. Binary data - nominal data with two mutually exclusive categories, eg. presence-absence type data.

The variables measured for each sample are listed under the appropriate data type in Table 4.

Table 4

Types of Variables Measured in Sample Descriptions

Numeric	Ordered Multistate	Unordered Multistate	Binary
mineralogic composition	grainsize	color	presence or absence of:
proportion of clast, matrix and cement	sorting		laminations
	roundness		cross-laminations
	degree of calcareousness		carbonaceous partings
	scale of laminations		graded bedding
	scale of graded bedding		ripple marks
	scale of soft sediment deformation		plant remains

Grain size was expressed as one of eleven size categories based on the Wentworth grade scale, rather than in millimetres directly, and therefore is ordered multistate-type data.

In order to derive similarity measures which are functions of every data type present, all data must be reduced to the form of the simplest type, in this case, the binary form. This reduces the information content of numeric data, but allows the inclusion of a large amount of data which would otherwise be unusable. This approach seems valid inasmuch as the purpose of this study is not to assess the variation of any one one component, but to arrive at a meaningful classification for each sample.

Data for each sample in this study were expressed in binary form as a series of 2's, 1's and 0's; where 2 indicates the presence of a certain characteristic, 1 its absence and 0 non-measurement or missing data. The method of conversion for variables of each data type is as follows (Bonham-Carter, 1965; Wishart, 1969):

a) Binary data - One category was allotted for each characteristic and either 1 or 2 entered in it to indicate the absence or presence respectively of that characteristic.

b) Unordered multistate data - Color was the only variable of this type in this study. Categories encompassing all possible colors were set up. 2 was entered in the appropriate color category for each sample, and 1 in all other color categories.

c) Ordered multistate data - Categories encompassing all subdivisions of the ordinal scale were set up. Calcareousness, for example, was represented by two binary

categories; slightly and very. If a sample was slightly calcareous, a 2 would be entered under slightly and a 1 under very. If a sample was very calcareous, 2's would appear in both categories. Grain size represents a special case in this study as a range in grain size grades as well as a mean grain size was estimated for each sample. In order to represent this, the number of binary categories allotted to grain size was doubled. If, for example, the mean grain size of a sample was fine sand size, and the range from very fine to medium sand, 2's would be entered in both binary categories representing fine sand and in one category of each of the very fine and medium sand grades (the one adjacent of the fine sand grade categories). This effectively doubles the weight attached to grain size in the calculation of similarity coefficients (Fig. 5).

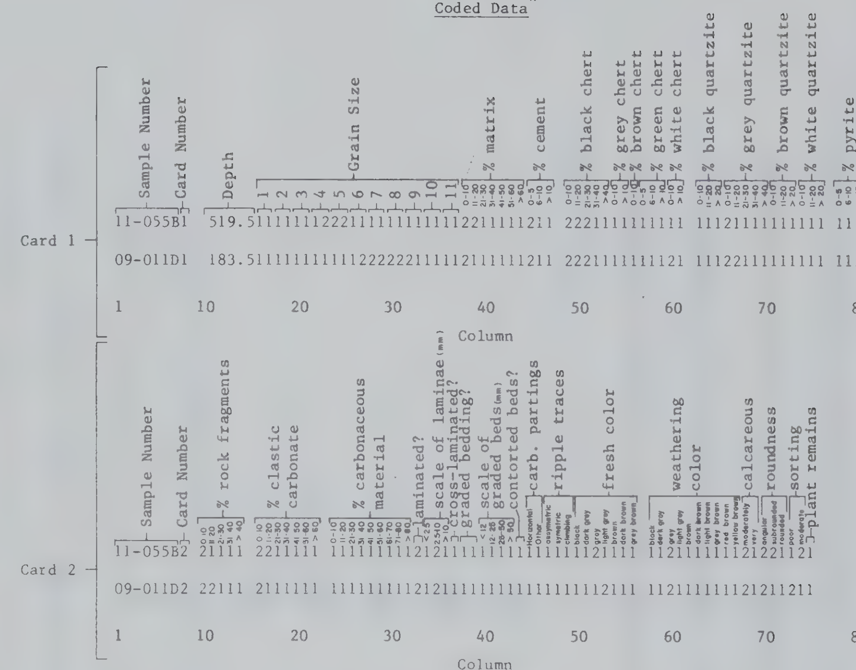
d) Numeric data - All numeric data in this study were also proportions and thus formed closed arrays. Such arrays can be completely defined by n-1 elements where n is the total number of elements in the array. Thus, the clast-matrix-cement system was defined by the proportions of matric and cement, and the mineralogic system by all components excluding quartz (which is present in nearly every sample). The values of each component in each of these two systems were determined and a series of percentage categories was set up to include all possible values for that component. Accuracy in estimation of components

Figure 5 Example of Data Conversion and Similarity Coefficient Calculation

Initial Data

Sample Number	- 09-11D	- 11-55B
Depth (feet)	- 183.5	- 519.5
Grain Size - Mean	- 1.5 mm.	- .375 mm.
- Range	- .25 - 4 mm.	- .125 - .5 mm.
Composition - % clasts	- 85	- 75
- % matrix	- 10	- 20
- % cement	- 5	- 5
Mineralogic		
Composition - % black chert	- 25	- 25
- % grey chert	- 0	- 0
- % brown chert	- 0	- 0
- % green chert	- 0	- 0
- % white chert	- 5	- 0
- % black quartzite	- 0	- 0
- % grey quartzite	- 20	- 10
- % brown quartzite	- 0	- 0
- % green quartzite	- 0	- 0
- % white quartzite	- 0	- 0
- % rock fragments	- 15	- 5
- % clastic carbonate	- 10	- 20
- % carbonaceous material	- 0	- 0
- % quartz	- 25	- 40
Structures - laminated?	- yes	- yes
- scale of laminations	- 6 mm.	- 6 mm.
- cross-laminated?	- no	- no
- graded bedding?	- no	- no
- scale of graded beds	- -	- -
- contorted bedding?	- no	- no
- carbonaceous partings?	- no	- no
- assymetric ripple traces?	- no	- no
- symmetric ripple traces?	- no	- no
- climbing ripple traces?	- no	- no
Color - fresh surface	- light grey	- grey
- weathered surface	- grey	- grey
Plant remains?	- no	- no
Rock Name	- very coarse grained ss.	- medium grained ss.
Calcareous?	- moderately	- moderately
Roundness of clasts	- sub-rounded	- sub-rounded
Sorting of clasts	- poor	- moderate

Coded Data*



* 0 = nonmeasurable characteristic
1 = absence of characteristic
2 = presence of characteristic

Grain Size Code

1 = less than 1/256 mm.
2 = 1/256 - 1/16 mm.
3 = 1/16 - 1/8 mm.
4 = 1/8 - 1/4 mm.
5 = 1/4 - 1/2 mm.
6 = 1/2 - 1.0 mm.
7 = 1.0 - 2.0 mm.
8 = 2.0 - 12.0 mm.
9 = 12.0 - 25.0 mm.
10 = 25.0 - 50.0 mm.
11 = greater than 50 mm.

Number of positive matches = 13

Number of negative matches = 99

Jaccard's coefficient = 13/112 = .1161

which make up a large portion of the system (i.e. greater than 20%) was probably no better than +5%, and for this reason categories with increments of 10% were used. If, for example, the maximum amount of black chert found in the samples was 50%, the following five categories would be set up:

0 - 10%

11 - 20%

21 - 30%

31 - 40%

41 - 50%

If a sample had 25% black chert, 2's would appear in the first 3 categories and 1's in the last two. Increments of 5% were used for some components which characteristically appear in small but possibly significant amounts, and whose proportions (owing to the small amount present) can usually be estimated with greater than +5% accuracy.

Figure 5 shows how data were converted from their original form to a string of 1's, 2's and 0's. In this study each sample was represented by 125 categories.

II. Similarity Coefficient Calculation

Numerous similarity measures have been proposed for use with two-state, presence-absence type data (Sokal and Sneath, 1963). Jaccard's coefficient, which has been used in a similar exercise to subdivide Recent carbonates off Andros island (Bonham-Carter, 1965), seemed most appropriate for this study. Jaccard's coefficient is

defined as follows:

$$J = P/(P + U) \quad \text{where } J = \text{Jaccard's coefficient}$$
$$P = \text{no. of positive matches}$$
$$U = \text{no. of negative matches}$$

Thus, if 2's are present in the same category for two samples a positive match is recorded and if 1's are present a negative match is recorded. Any match which involves a zero is omitted from the similarity coefficient calculation. This brings in the concept of relevance discussed by Sokal and Sneath (1963, p. 165). They defined relevance as:

$R = a_{jk}/n$ where: a_{jk} - is the actual number of comparisons between samples j and k

n - is the possible number of comparisons

and point out that values below 0.5 to 0.7 are to be avoided. Relevance was not considered in this study as those samples with a high proportion of missing data and correspondingly low relevance values almost always occured in the claystone and coal group, where data such as mineralogic composition and range in grain size are difficult to obtain due to the small size of clasts. Zeros (missing or non-measurable data) are likely to be recorded in the same categories for samples in this group (this is the reason for the large number of perfect similarities seen in Fig. 6A), and therefore similarity coefficients between samples are based on a smaller but relatively constant number of comparisons.

III. Cluster Analysis

The Dendrograph program described by McCammon and Wenninger (1970) employs an unweighted pair-group method of cluster analysis. Similarity coefficients are first converted to distance-type measures by an arc cosine transformation (McCammon and Wenninger, 1970, p. 2).

The two groups of variables which when combined have the lowest average within-group pairwise distance are joined in each stage of clustering (Lance and Williams, 1967, p. 375). If two groups i and j are joined to form group k, the average within-group pairwise distance between k and a third group h is defined by the following formula (Lance and Williams, 1967, p. 375):

$$d_{hk} = \frac{n_i}{n_k} \cdot \frac{1}{n_h n_i} \cdot \sum_{h,j} S_{hi} + \frac{n_i}{n_k} \cdot \frac{1}{n_h n_j} \cdot \sum_{h,j} S_{hj}$$

where: d_{hk} = average within-group pairwise distance between groups h and k

n_i = number of elements in group i

S_{hi} = interelement measure between h and i

By taking the cosine of d_{hk} the average within-group correlation can be determined. The average between-group pairwise distance is similarly calculated and converted to correlation units by taking its cosine. The within-group correlation is plotted on the ordinate and the between-group correlation on the abscissa of the dendrograph, and thus a 2-dimensional representation of similarity is achieved, unlike the 1-dimensional representation portrayed by conventional dendrograms. McCammon (1968), documents the rule for ordering the variables so that a pyramidal shape is achieved in the resulting dendrograph. Input into this program consists of a lower triangular matrix of similarity coefficients for each of the five basic groups of samples listed previously (p. 26). Output consists of the dendrographs (Fig. 6) and printout giving the clustering order and within-group and between-group distances in correlation units.

The number of variables on which a similarity coefficient is based may vary from sample to sample as certain variables may not be

measured in every sample. Tests of the significance of groupings displayed by dendrograms and dendrographs are complicated when dealing with similarity coefficients which are not consistently a function of the same variables, as it is not clear how to choose the number of degrees of freedom for such tests (Bonham-Carter, 1965; McCammon, 1968). Further complications in applying significance tests arise if percentage type data, which form closed arrays, are included in similarity coefficient calculation (Chayes and Kruskal, 1966). For these reasons, no formal tests of significance of the twenty-six lithotypes derived by cluster analysis were undertaken. Instead, the suggestion of McCammon (1968, p. 1666) that the significant number of clusters depicted in a dendrograph can be qualitatively estimated "...by matching the wider gaps between hierarchical levels with the wider spacings between the clusters..." was followed in the course of interpreting the dendrographs in this study.

The level of similarity at which groups are connected is an indication of their significance and the method of cluster analysis employed. If no similarities exist between samples or groups, they should theoretically be connected at similarity levels at or near zero. On this basis, lithotypes chosen on Figure 6 appear to be significant as they contain smaller groups and samples in no case connected at similarity levels of less than 0.5. Also, several of the first and last samples to join each lithotype in the clustering process were examined in order to gain an idea of the range in value of different variables within each lithotype, and in so doing, to assess the validity of that lithotype. From the general descriptions of each lithotype given below, it is evident that there are overlaps between lithotypes

with respect to certain variables. This is apparently a function of the lack of precision in the way the similarity coefficients were calculated. In general, however, each group has its own distinct characteristics and appears to be a geologically valid subdivision.

Lithotype descriptions are as follows:

Lithotype 1 (Fig. 6A) - Claystone; silty in part, carbonaceous, very thinly laminated to laminated, dark grey, weathers grey, non- to slightly calcareous.

Lithotype 2 (Fig. 6A) - Claystone; silty in part, plant fragments and carbonaceous partings present, laminated, dark grey to black, weathers dark grey, non-calcareous.

Lithotype 3 (Fig. 6A) - Claystone; silty in part, massive, dark grey, weathers grey, slightly to very calcareous.

Lithotype 4 (Fig. 6A) - Claystone; carbonaceous, thinly laminated, grey, weathers grey to grey-brown, calcareous in part.

Lithotype 5 (Fig. 6A) - Coal.

Lithotype 6 (Fig. 6B) - Siltstone; sandy in part, 10 to 25% matrix and cement, dark grey to grey, weathers grey to light grey, calcareous, clasts subangular to subrounded, moderately sorted, clast composition is as follows:

10 to 35% black chert

10% rock fragments

20 to 40% carbonate

35 to 40% quartz

Lithotype 7 (Fig. 6B) - Siltstone; muddy in part, 30 to 40% matrix and cement, mainly massive although thinly laminated in part, dark grey to grey, weathers grey-brown to yellow-brown, clasts subangular, moderately sorted, clast composition is as follows:

0 to 15% black chert

5 to 10% rock fragments

30 to 60% carbonate

35 to 50% quartz

Lithotype 8 (Fig. 6B) - Siltstone; muddy in part, 30 to 55% matrix and cement, thinly laminated, laminae contorted in part, dark grey, weathers grey to grey-brown, calcareous in part, clast composition is as follows:

0 to 10% black chert

0 to 5% rock fragments

0 to 2% carbonaceous material

0 to 20% carbonate

60 to 80% quartz

Lithotype 9 (Fig. 6B) - Siltstone; muddy, 35 to 80% matrix and cement, laminated, carbonaceous

partings and plant remains present, weathers dark grey to grey, dark grey, calcareous, moderately sorted, clast composition is as follows:

0 to 15% black chert

10 to 30% carbonate

0 to 5% carbonaceous material

0 to 10% rock fragments

30 to 50% quartz

Lithotype 10 (Fig. 6B) - Siltstone; 60 to 70% matrix and cement, laminated in part, dark grey to grey, weathers dark grey to grey, non-calcareous, clasts subangular, poorly sorted, clast composition is as follows:

10 to 15% black chert

10% rock fragments

0 to 5% carbonate

70 to 80% quartz

Lithotype 11 (Fig. 6C) - Siltstone; 30 to 55% matrix and cement, laminated, cross-laminated in part, dark grey to grey, weathers grey, calcareous, clasts subangular, poorly sorted, clast composition is as follows:

10 to 20% black chert

5 to 10% rock fragments

20 to 60% carbonate

10 to 65% quartz

Lithotype 12 (Fig. 6C) - Sandstone; very fine grained, 15 to 25% matrix and cement, thinly laminated to laminated, cross-laminated in part, dark grey, weathers grey, calcareous in part, clasts subangular to angular, moderately well sorted, clast composition is as follows:

15 to 35% black chert

5 to 10% rock fragments

5 to 40% carbonate

40 to 45% quartz

Lithotype 13 (Fig. 6C) - Sandstone; very fine to fine grained, 15 to 25% matrix and cement, thinly laminated to laminated, cross laminated in part, dark grey, weathers grey to grey-brown, calcareous, clasts subangular to angular, moderately to well sorted, clast compostion is as follows:

20 to 25% black chert

5 to 10% rock fragments

25 to 30% carbonate

35 to 50% quartz

Lithotype 14 (Fig. 6C) - Sandstone; very fine grained, 10 to 25% matrix and cement, laminated to

thinly laminated, dark grey, weathers grey, slightly calcareous, clasts subangular, moderately to poorly sorted, clast composition is as follows:

20 to 25% black chert

5 to 10% rock fragments

15 to 20% carbonate

50 to 60% quartz

Lithotype 15 (Fig. 6C) - Sandstone; fine grained, 10 to 20% matrix and cement, laminated, cross-laminated in part, dark grey to grey, weathers grey, calcareous, clasts subangular, moderately to well sorted, clast composition is as follows:

5 to 20% black chert

5 to 10% rock fragments

30 to 50% carbonate

30 to 55% quartz

Lithotype 16 (Fig. 6C) - Sandstone; fine grained, 10 to 20% matrix and cement, laminated, dark grey to grey, weathers grey to grey-brown, slightly calcareous, clasts subangular, moderately well sorted, clast composition is as follows:

15 to 20% black chert

5 to 10% rock fragments

15 to 30% carbonate

45 to 65% quartz

Lithotype 17 (Fig. 6C) - Sandstone; very fine to fine grained, 10 to 15% matrix and cement, thinly laminated, cross-laminated, grey, weathers grey to grey-brown, slightly calcareous, clasts angular to subangular, moderately sorted, clast composition is as follows:

10 to 15% black chert

5 to 10% rock fragments

0 to 25% carbonate

35 to 50% quartz

Lithotype 18 (Fig. 6D) - Sandstone; fine to medium grained, less than 15% matrix and cement, laminated to thinly laminated, cross-laminated in part, dark grey to grey, weathers grey to grey-brown, slightly calcareous, moderately well sorted, clasts subangular, clast composition is as follows:

10 to 20% black chert

5% rock fragments

15 to 30% carbonate fragments

50 to 60% quartz

Lithotype 19 (Fig. 6D) - Sandstone; medium to coarse grained, less than 15% matrix and cement,

thinly laminated to massive, dark grey to grey, weathers grey to light brown, slightly calcareous, clasts subangular, moderately to well sorted, composition of clasts is as follows:

15 to 30% black chert

0 to 20% grey quartzite

0 to 15% brown quartzite

5 to 10% rock fragments

5 to 35% carbonate

20 to 45% quartz

Lithotype 20 (Fig. 6D) - Sandstone; medium to very coarse grained, less than 10% matrix and cement, massive, light grey, weathers grey-brown to light grey, non-calcareous, clasts subangular to rounded, moderately well sorted, composition of clasts is as follows:

10 to 20% black chert

0 to 5% green chert

5 to 15% rock fragments

0 to 5% carbonate

70 to 85% quartz

Lithotype 21 (Fig. 6D) - Sandstone; coarse to very coarse grained, 10 to 20% matrix and cement, laminated to thinly laminated,

massive in part, grey to grey-brown, weathers grey to light grey, calcareous, clasts subangular to rounded, moderatley to poorly sorted, composition of clasts is as follows:

15 to 20% black chert
10% rock fragments
20 to 35% carbonate
40 to 55% quartz

Lithotype 22 (Fig. 6E) - Sandstone; very coarse grained to pebbly, 15 to 25% matrix and cement, massive, grey to dark grey, weathers grey, slightly calcareous, clasts subangular to rounded, moderately to poorly sorted, composition of clasts is as follows:

20 to 25% black chert
0 to 1% green chert
15 to 40% grey quartzite
15 to 25% rock fragments
0 to 10% carbonate
10 to 40% quartz

Lithotype 23 (Fig. 6E) - Conglomerate; clasts range from 2 mm. to 50 mm. in diameter, 10 to 20% matrix, massive, grey to dark grey; weathers grey, non- to slightly calcareous, clasts rounded, poorly

sorted, clast composition is as follows:

20 to 30% black chert
0 to 5% green chert
0 to 5% white chert
10 to 20% grey quartzite
0 to 10% white quartzite
30 to 40% rock fragments
0 to 5% carbonate
10 to 30% quartz

Lithotype 24 (Fig. 6E) - Conglomerate; clasts range from sand size to 50 mm., less than 15% matrix and cement, mainly massive although laminated in part, grey to dark grey, weathers grey to grey-brown, non- to very slightly calcareous, clasts rounded, poorly sorted, clast composition is as follows:

20% black chert
25 to 30% quartzite
15 to 20% rock fragments
0 to 15% carbonate
15 to 30% quartz

Lithotype 25 (Fig. 6E) - Conglomerate; sandy, clasts range from coarse sand size to 25 mm. in diameter, 45 to 70% matrix and

cement, massive in part, some samples show graded bedding, grey, weathers grey to grey-brown, non-calcareous, clasts sub-rounded and poorly sorted, clast composition is as follows:

20 to 30% black chert
0 to 15% grey quartzite
15 to 25% rock fragments
10 to 30% quartz

Lithotype 26 (Fig. 6E) - Conglomerate; clasts range in size from coarse sand to greater than 50 mm. in diameter, 15 to 30% matrix and cement, massive, grey to grey-brown, weathers grey-brown to red-brown, non-calcareous, clasts sub-rounded to rounded, poorly sorted, clast composition is as follows:

10 to 25% black chert
0 to 5% brown chert
5 to 30% green chert
0 to 5% white chert
5 to 25% grey quartzite
5 to 25% white quartzite
10 to 20% rock fragments
5 to 15% quartz

Figure 7 Manner of Combining Initial 26 Lithotype Groups for Classification Levels Recognizing 11 and 6 Lithotypes

	26 Lithotypes	11 Lithotypes	6 Lithotypes
Claystones	1, 2, 3	1	1
	4	2	
Coal	5	3	2
Siltstones	6, 7, 8, 9	4	3
	10, 11	5	
Fine Sands	12, 13, 14, 15	6	4
	16, 17	7	
Coarse Sands	18, 19, 20, 21	8	5
	22	9	
Conglomerates	23, 24, 25	10	6
	26	11	

After assigning each sample to a lithotype, the Mount Allan, Wind Ridge and Three Sisters sections were represented by a string of numbers, each referring to the lithotype of a sample taken at some distance from the start of each measured section. In order to estimate the relative abundance of various lithotypes in each section, and to make allowance for the thickness of rock units in correlation, it was necessary to have equally spaced observation points along each section. Observation points at two foot intervals were set up for each section by assigning to each observation point the lithotype of the sample taken nearest it. Diagrams illustrating the relative abundance of lithotypes with position in each of the Mount Allan, Wind Ridge and Three Sisters sections appear in Appendix C. Figure 7 illustrates the manner in which the initial 27 lithotypes were combined according to the dendrographs (Fig. 6) to yield classification levels recognizing 11 and 6 lithotypes.

Chapter Five

CORRELATION

Correlation of the Wind Ridge and Three Sisters sections to the Mount Allan section was approached in two ways. The first entailed the use of cross-correlation using only grain size data at points spaced at three-foot intervals along the sections. This was done by Digitech Systems Co. Ltd. of Calgary. The second used a cross-association program from Davis (1973) and the lithotypes derived in chapter 4. In either case, the resulting correlation is of an approximate "best-fit" nature.

I. Cross-Correlation Using Grain Size

Grain size data from the Mount Allan, Wind Ridge and Three Sisters sections were equally spaced at three foot intervals by assuming the mean grain size of the sample nearest to the spacing point to be representative of the grain size at that point.

The Mount Allan section was designated the reference section and the Wind Ridge and Three Sisters sections were compared to it at all possible match positions. At each match position a correlation coefficient with a value ranging from -1.0 (perfect negative correlation) to 1.0 (perfect correlation) was calculated using a formula of the form (Davis, 1973, p. 243):

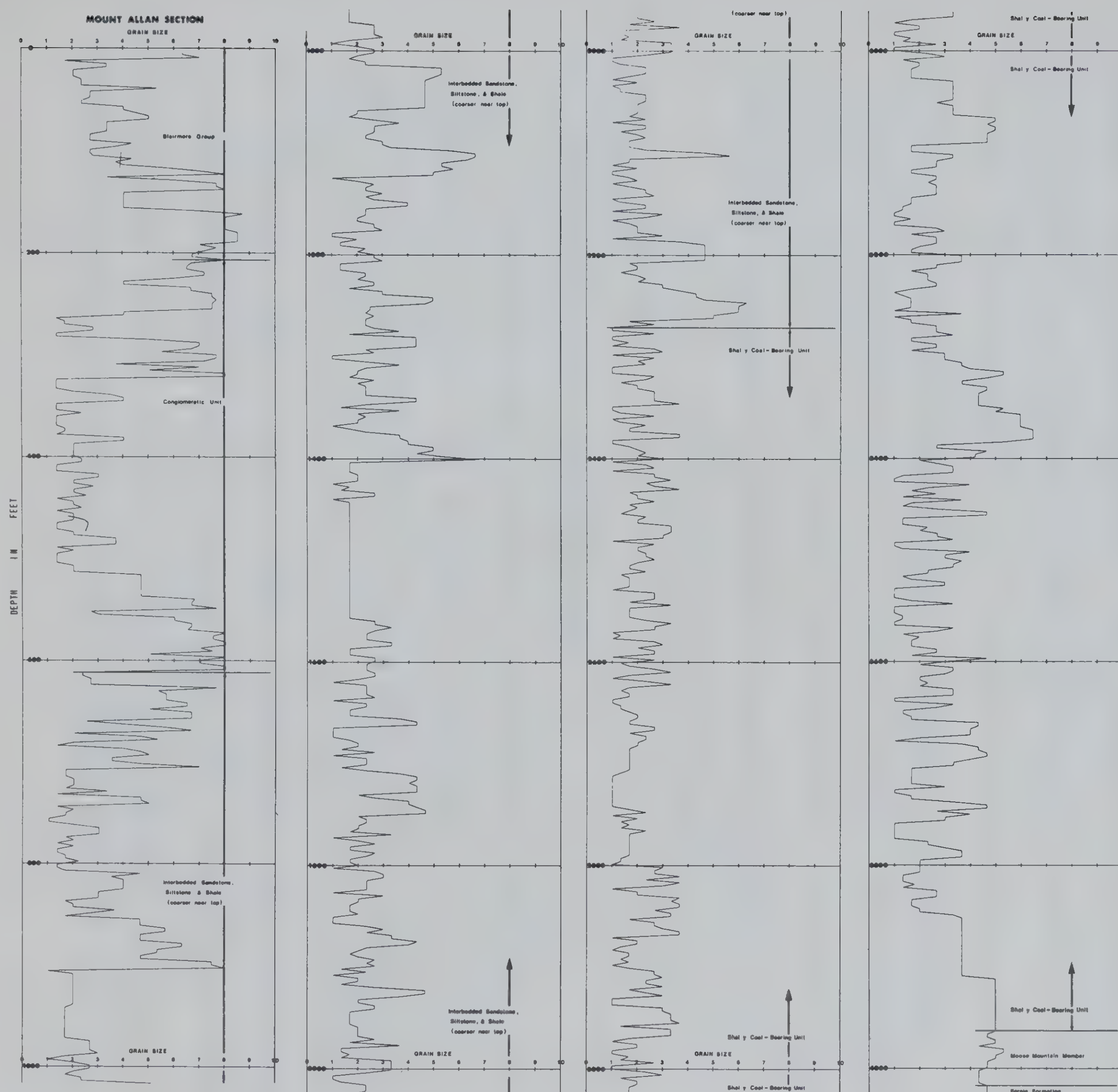
$$r = n\sum Y_1Y_2 - \sum Y_1 \sum Y_2 \ / \sqrt{(n\sum Y_1{}^2 - (\sum Y_1)^2) \ (n\sum Y_2{}^2 - (\sum Y_2)^2)}$$

where n = the number of terms in the subsidiary section

Y_1 = the terms in the reference section being compared to the subsidiary section

Y_2 = the terms in the subsidiary section

The significance of a correlation coefficient may be approximately tested against a null hypothesis of no correlation using the



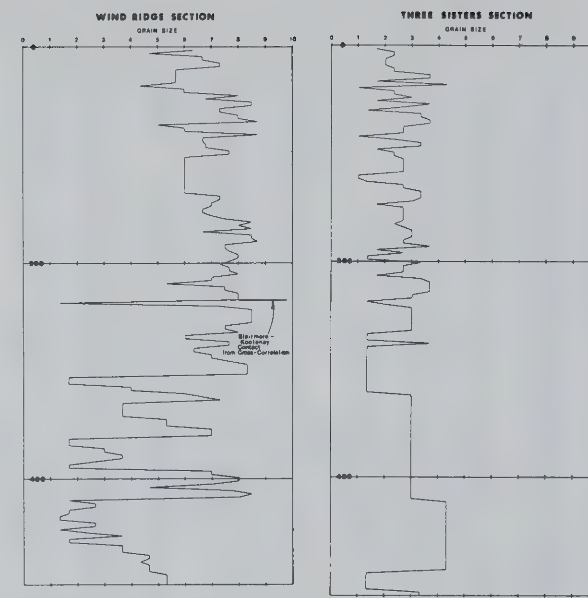


Figure 8 GRAIN SIZE DISTRIBUTION

IN

MOUNT ALLAN, WIND RIDGE and

THREE SISTERS SECTIONS

Grain Size Code

1	–	< 1/256 mm.
2	–	1/256 – 1/16 mm.
3	–	1/16 – 1/8 mm.
4	–	1/8 – 1/4 mm.
5	–	1/4 – 1/2 mm.
6	–	1/2 – 1.0 mm.
7	–	1.0 – 2.0 mm.
8	–	2.0 – 12.0 mm.
9	–	12.0 – 25.0 mm.
10	–	25.0 – 50.0 mm.

t test statistic (assuming grain size in the section is normally distributed) which is defined as (Davis, 1973, p. 243):

$$t = r\sqrt{n - 2/\ 1 - r^2} \text{ -degrees of freedom} = n - 2$$

The correlation program used by Digitech Systems Co. Ltd. begins by comparing all points in the subsidiary section to the uppermost points in the reference section, calculates a correlation coefficient, then moves the subsidiary section down one position (three feet) and calculates another coefficient. If m represents the number of points in the reference section and n the number in the subsidiary section, m-n comparisons are made. This assumes the best possible match position lies somewhere within the reference section, and does not allow for the possibility that the best match may occur when only part of the subsidiary section is compared to the reference section (a possibility which is allowed for in the cross-association approach discussed below). Output from the cross-correlation program consists of a correlation coefficient versus match position plot.

Grain size distribution within the measured sections is shown in Figure 8.

II. Cross-Association Using Lithotypes

Cross-association involves the matching of equally spaced nominal data, in this case lithotypes. Lithotypes for all three sections were equally spaced at two foot intervals by assuming the lithotype nearest a spacing point as representative of the lithotype at that point. Each measured section in this manner was represented by a chain of lithotype codes. Sections were then compared to each other at successive match positions. At each match position, the total number of matches and mismatches was determined. The best fit or

correlation occurs when the number of matches reaches a maximum.

The probability of a match at any position between two random chains is (Davis, 1973, p. 248):

$$Pr = \sum_{k=1}^{m} X_{1k} \, X_{2k} \, / \, n_1 \, n_2$$

where: m = number of categories (lithotypes)

X_{1k} = number of observations of the k^{th} category

X_{2k} = number of observations of the k^{th} category

n_1 = length of chain 1

n_2 = length of chain 2

The mean number of expected matches between two random chains compared at X match positions, $\overline{E}$, is (Davis, 1973, p. 251):

$$\overline{E} = X \, (Pr)$$

The distance from $\overline{E}$ in units of standard deviation can be used as an index of correlation. This distance, S, is calculated from (Davis, 1973, p. 251):

$S = 0 - \overline{E} \, / \, \overline{E} \, (1 - Pr)$ where 0 = the observed number of matches.

The cross-association program of Davis (1973) computes for each match position; the standard deviation from the random mean, the percentage of matches, the chi-squared statistic, the chi-squared statistic modified for small data sets with the Yates correction factor, and a normal approximation to the binomial deviation (Z). The chi-squared statistic is calculated using the formula (Davis, 1973, p. 250):

$$X^2 = (0 - \overline{E})^2 \, / \, \overline{E} + (0' - \overline{E})^2 \, / \, \overline{E}' \; -1 \text{ degree of freedom}$$

where: 0 = observed number of matches

$0'$ = observed number of mismatches

$\overline{E}$ = expected number of matches

$\overline{E}'$= expected number of mismatches

The Yates correction factor can be used to correct for small data sets such as at the ends of chains where the number matches is small. The Chi-square statistic then becomes (Davis, 1973, p. 250):

$$X^2 = (0 - \overline{E} - \tfrac{1}{2})^2 \, / \, \overline{E} + (0' - \overline{E}' - \tfrac{1}{2})^2 \, / \, E$$

The probability of obtaining a given deviation from the binomial mean $\overline{E}$ can be evaluated using standardized normal tables by creating a normal approximation (Z) to the deviation using the formula (Davis, 1973, p. 251):

$$Z = X \, (2 \arcsin \; 0/X - 2 \arcsin \; Pr)$$

In contrast to the cross-correlation program of Digitech Systems Co. Ltd., the cross-association program begins by comparing the lowermost y observations of the subsidiary section to the uppermost y observations of the reference section, where y is defined as:

$$y = 1.0/Pr + 1$$

Thus the possibility that the best match may occur when only part of the subsidiary section is compared to the reference section is not discounted.

III. Correlation Results

A. Wind Ridge Section

Cross-association between the Wind Ridge and Mount Allan sections was carried out at subdivision levels recognizing twenty-six, eleven and six lithotypes. Comparison of the position and magnitude of correlation maxima derived from cross-association and cross-correlation can be made using Figure 9. The magnitudes of cross-association correlation maxima are expressed in terms of the normal

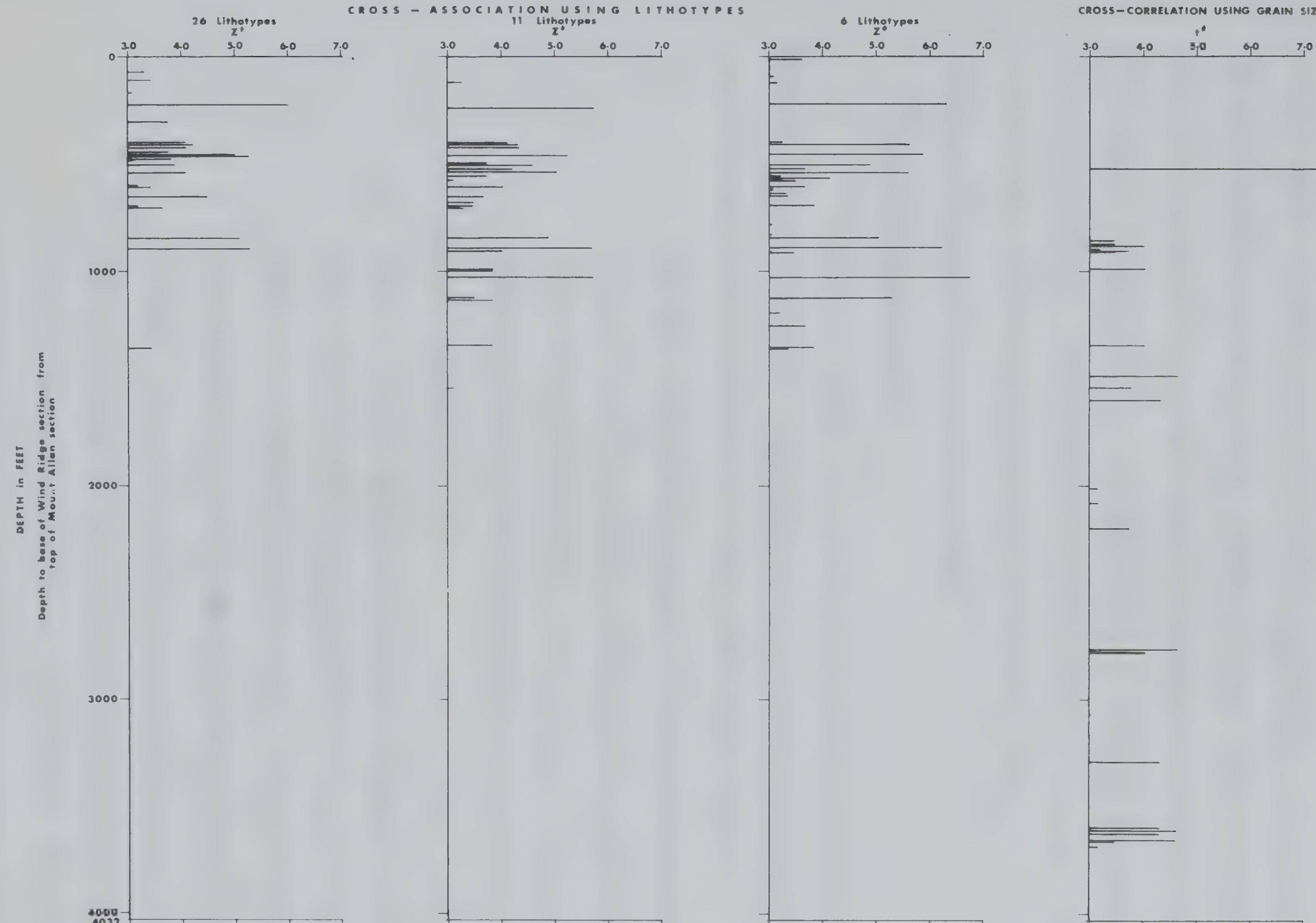
approximation to the deviation from the binomial mean, Z, discussed above. The probability of Z exceeding 3.0 in cross-association between two random chains is less than 0.13 percent. The magnitudes of correlation maxima derived from cross-correlation are expressed in terms of the t test statistic. Maxima at which t exceeds 3.0 are significant at the 99.9 percent level.

The following observations can be drawn from Figure 9:

1. The number and degree of scattering of correlation maxima for cross-association appears to increase as the subdivision level is simplified and thus in this case the recognition of more lithotypes appears to be useful in isolating the best correlation.
2. The best correlation using cross-correlation occurs when the base of the Wind Ridge section is 519 feet below the top of the Mount Allan section and a zone of high correlation occurs between 400 and 550 feet for cross-association. In this case at least it seems that grain size is as valuable a parameter for correlation as those involved in lithotype definition, although spurious maxima below 1500 feet using cross-correlation are eliminated using cross-association.

The best correlation occurs when the base of the Wind Ridge section is between 400 and 550 feet below the top of the Mount Allan section. If this is the case the conglomerates near the top of the Wind Ridge section, on a lithologic basis at least, should be included in the Blairmore Group. Most authors to date (Dowling, 1907; Crockford,

Figure 9 CORRELATION MAXIMA for WIND RIDGE and MOUNT ALLAN SECTIONS



* Z – Normal approximation to the deviation from the binomial mean (see text)

* t – t test statistic

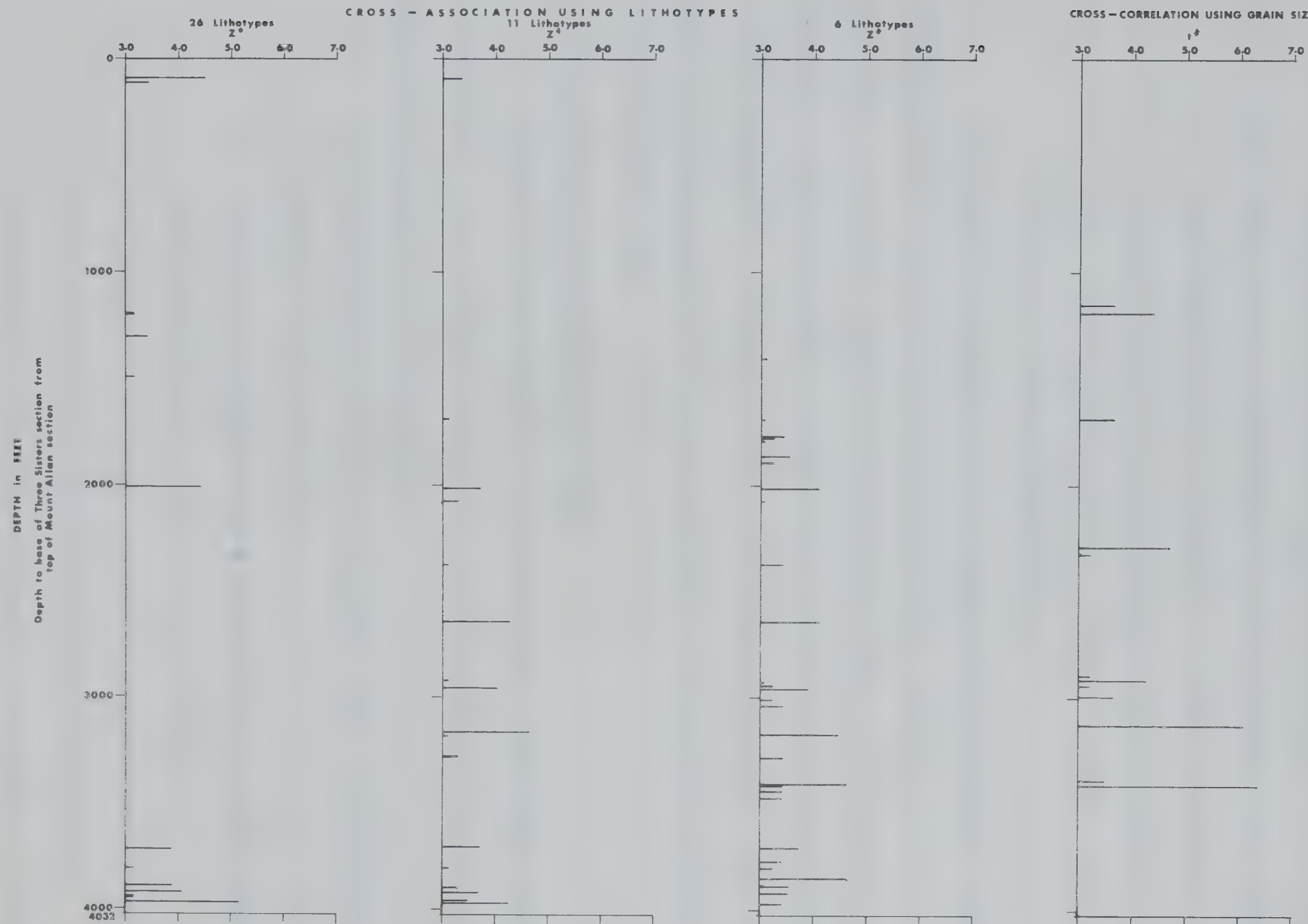
1949; Norris, 1957; Price, 1970) except for MacKay (1935), have placed these conglomerates in the Kootenay Formation, mainly because of the smaller pebble size and thinner conglomerate beds encountered on Wind Ridge relative to those on Mount Allan. These differences might be accounted for by the lateral inhomogeneity of the fluviatile environment responsible for the deposition of these conglomerates, and the characteristic lenticularity of deposits of this type. Rapson (1964) noted rapid lateral thickness variations in beds of the basal Blairmore conglomerates on Mount Allan.

B. Three Sisters Section

Correlation maxima for cross-association and cross-correlation between the Three Sisters and Mount Allan sections appear in Figure 10. The following observations can be drawn from this Figure:

1. The most significant maxima for cross-association recognizing 11 and 6 lithotypes and for cross-correlation, occur when the base of the Three Sisters section is between 2900 and 3450 feet below the top of the Mount Allan section.
2. There is little apparent agreement between correlation maxima derived from cross-association using 26 lithotypes and cross-association using 11 and 6 lithotypes. This suggests the existence of subtle differences in sediment type and sequence between the Mount Allan and Three Sisters area, which are obscured as the subdivision level is simplified. If this is the case correlation maxima derived from cross-association using 11 and 6 lithotypes are more meaningful as they are less

Figure 10 CORRELATION MAXIMA for THREE SISTERS and MOUNT ALLAN SECTIONS



Z – Normal approximation to the deviation from the binomial mean (see text)

t – t test statistic

sensitive to such variations, and the best correlation occurs when the base of the Three Sisters section is about 3150 feet below the top of the Mount Allan Section.

3. High correlations below 3700 feet derived from cross-association can be attributed to large proportions of covered intervals near the base of both the Mount Allan and Three Sisters sections (covered intervals were coded as a separate lithotype).

The best correlation for the Three Sisters section occurs when the base of the section is about 3150 feet below the top of the Mount Allan section. Thus the Three Sisters section correlates with the shaly coal-bearing unit on Mount Allan and the lower part of the "upper submember" of Jansa's (1972) "coal-bearing member". This conclusion is supported by coal seam thickness and continuity observed in outcrop in this study.

C. Discussion of Correlation Results

There are limitations to the use of only lithologic data for correlation. If a perfect correlation is to be achieved between stratigraphic sections in two localities:

1. The sedimentation rate at a given time must have been the same for both localities.
2. The type of sediment being deposited at a given time must have been the same in both localities.
3. The amount of sediment removed by erosion on disconformities within each section must have been constant.
4. The sampling scheme must be such that samples are representative of the type and sequence of lithologies

actually present in each section.

The first three assumptions obviously do not hold for real stratigraphic problems, and thus the resulting correlation must be approximate at best. The degree to which they influence the final correlation is a function of the variability of the environment of deposition of the strata and the distance between sections to be correlated.

The presence of a zone of correlation maxima between the Wind Ridge and Mount Allan sections rather than one distinct peak is both a function of the method used and lateral facies changes between the two sections. In general, however, correlation maxima derived from cross-association at all three classification levels, and cross-correlation agree quite well. The lack of agreement between correlation maxima derived using cross-association at a classification level recognizing 26 lithotypes and those derived using cross-association recognizing 11 and 6 lithotypes for correlation between the Three Sisters and Mount Allan sections is probably a reflection of more extensive facies changes between these sections, relative to those between the Wind Ridge and Mount Allan sections. These facies changes are evident at a classification level recognizing 26 lithotypes but are lost at classification levels where only 11 and 6 lithotypes are recognized.

Chapter Six

CYCLICITY ANALYSIS

Cyclical fluctuations of climatic elements are evident in most depositional environments. These cycles may vary in period from minutes or hours, such as diurnal fluctuations in temperature and water level; to years such as seasonal fluctuations and sunspot cycles; to thousands or millions of years such as glacial and galactic cycles. The degree to which these cycles are reflected in sediments is a function of the intensity with which they affect factors which directly control deposition such as sediment type and supply. The effect of these cycles may be partially or wholly obscured by tectonic phenomena, which may cause gradual, non-cyclic change, in environments, or complicated by the presence of several cycles with different periods acting simultaneously. By demonstrating the presence of lithologic cycles in sediments, insights into the nature of their depositional environment may be obtained.

Most numerical attemps to detect cyclicity in sediments to date have employed data from the Carboniferous coal measures of the eastern United States. The cyclical nature of these sediments is apparent from field observations (Moore, 1936), but is somewhat difficult to verify statistically (Schwarzacher, 1969; Davis and Cocke, 1972). This is because partial or incomplete cycles are more common than complete or ideal cyclothems (Moore, 1936). Within the Kootenay Formation, no such obvious cycles are evident in the field. Lithogies present in fact indicate a gradation caused by tectonism from the prodelta facies of the upper Fernie Formation, to the alluvial plain environment of the Blaimore Group. Any lithologic cyclicity

therefore, must reflect short period oscillations in depositional environments, relative to the gradual environmental change. The Mount Allan section of the Kootenay Formation was examined for such lithologic cyclicity using the techniques of auto-association (Sackin and Merriam, 1970) and substitutability analysis (Davis and Cocke, (1972).

I. Limitations of Cyclicity Analysis Techniques

Several assumptions are inherent in the use of lithologic data and numerical techniques to evaluate cyclicity. If the thickness of individual rock units as well as their order is taken into account in the definition of a cycle, the following factors most hold for absolute uniformity between cycles:

1. The oscillating environmental elements controlling sedimentation must be stationary. That is, there can be no overall gradation from one environment to another with time.
2. The sedimentation rate at any given point within a cycle must be constant for each cycle.
3. The sediment type supplied at any given point within a cycle must be the same for each cycle.
4. Erosion, if it occurs, must occur at the same rate and position within each cycle.

In addition the following considerations must be taken into account to avoid obscuring cyclicity:

1. The interval examined for cyclicity should be large relative to the expected period of cycles, so that enough cycles are present to verify their existence

statistically.

2. If a sampling plan calling for equally spaced samples is used, the sample interval must be small enough so that no lithologies are missed.

3. Assignment of samples to rock types must be consistent.

By employing a definition of cyclicity in which only the sequence and not the thickness of rock units is considered, the effect of non-constant sedimentation rates between cycles is eliminated, and erosion becomes important only if one or more rock units are differentially removed. Inferences as to the causative processes and applicability of the analysis to geologic problems such as correlation and mapping may be restricted by such a definition, however, as Schwarzacher (1969) pointed out. The effect of non-stationarity or a gradual overall change in environments can be minimized by examining intervals for cyclicity which are likely to represent long periods of time relative to the duration of an individual cycle, but which are short relative to the overall change.

II. Numerical Techniques in Cyclicity Analysis

A stratigraphic section represented by a character string of distinct lithologic states, exhibits the Markov property if the lithologic state at a given point is dependent in a probabilistic manner on the immediately preceding state (Davis, 1973). A stratigraphic section with cyclic components represents a special type of Markov system which periodically returns to a given starting state. Numerical methods to detect cyclicity in sediments to date have employed such techniques as the analysis of the structure of transition probability matrices and testing for the presence of the Markov property

(Schwarzacher, 1969), auto-association (Sackin and Merriam, 1969) and substitutability analysis (Davis and Cocke, 1972). A brief review of each of these techniques follows.

A. Transition Probability Matrices

A one step transition probability matrix contains the conditional probabilities of one state following another. It can be derived from a character string representing lithologic states by tallying the number of transitions between states in a transition frequency matrix and dividing each entry in this matrix by the total number of transitions in its respective row (Davis 1973, p. 280). A transition probability matrix can be tested for the presence of the Markov property using a chi-square test (Anderson and Goodman, 1957), and three parameters useful in evaluating cyclicity can be derived from it (Schwarzacher, 1969, p. 20):

1. The probability of encountering a certain state after n steps can be obtained from the elements of the transition probability matrix raised to the power of n (transition probability). When n becomes large enough all columns in the matrix become equal and the transition probabilities reflect the abundance of each state in the sequence.
2. The probability that a given state will recur for the first time n steps from its initial occurrence (recurrence probability).
3. The probability of one state passing to another for the first time n steps from its initial occurrence (first-passage probability).

Plots of the transition, recurrence and first-passage probabilities versus n allow one to distinguish cyclic and non-cyclic sequences and assemble a "modal" cycle (Schwarzacher, 1969, p. 24). Cyclic sequences have the following characteristics.

1. A transition probability plot will show damped oscillations with a period equal to that of the cycle.
2. Recurrence probability maxima will occur at values of n equal to the period of the cycle.
3. First-passage probabilities for a given state will show maxima at values of n equal to the distance of that state from the initial state in the cycle.
4. The transition probability matrix will have some negative or complex eigenvalues. The modulus of the complex roots of such eigenvalues reflect the degree of damping of oscillations present and may be used, as suggested by Schwarzacher (1969, p. 24), to compare different cycles.

In some instances two-step and higher order transition probability matrices may be required to detect cyclicity (a two-step transition probability matrix contains the conditional probabilities of one state occuring two steps after another), as discussed by Schwarzacher (1969, p. 21).

B. Auto-association

Auto-association (Sackin and Merrian, 1969) is similar to cross-association as discussed in chapter 5, except that a character string is compared to itself at successive match positions or lags. Cycles within the string are reflected on auto-association versus lag plots as high auto-associations at intervals equal to their period.

Inferences as to the component states of cycles and their sequence may be obtained by manually scanning the character string, knowing the period of cycles likely to be present.

Auto-association is useful in that it is a simple technique to rapidly scan a character string and determine if cyclicity exists. It is particularly well suited to the analysis of sections which contain few transitions relative to the number of states involved, as may be the case when a larger section is analysed in small segments to avoid the masking effect of non-stationarity. Transition probability matrices derived from such short sections are not likely to represent enough transitions to be statistically significant. In addition, auto-association is probably best suited to studies where only the sequence and not the thickness of individual rock units is considered, as the addition of thickness information will tend to obscure cyclicity due to the influence of differnetial sedimentation and erosion rates, as discussed previously. Auto-association was employed in this study for these reasons.

Studies of cyclic Pennsylvanian rocks in the eastern United States utilizing auto-association have been conducted by Sackin and Merriam (1969) and Davis and Cocke (1972).

C. Substitutability Analysis

Substitutability (Davis and Cocke, 1972) is a measure of the degree to which two states occur in a common context, and is confined to the range 0.0 to 1.0. If two states tend to be followed by a common state, they have a high left substitutability, if they tend to be preceded by a common state, they have a high right substitutability, and if they tend to be preceded and followed by common states, they

have a high mutual substitutability. Substitutability analysis therefore provides a basis for combining states which occur in a common context and thus may clarify cycles obscurred by lithologic "substitutions" within them. It can be applied to both the analysis of transition probability matrices and auto-association. The left substitutability is calculated from the formula (Davis, 1973, p. 290):

$$L_{rs} = \sum_{j=1}^{m} Pr_{rj}\, Pr_{sj} \Big/ \sqrt{\sum_{j=1}^{m} Pr_{rj}^{2} \sum_{j=1}^{m} Pr_{sj}^{2}}$$

where: L_{rs} = left substitutability between states r and s

m = total number of states

Pr_{rj} = probability that state j follows state r

Pr_{sj} = probability that state j follows state s

The right substitutability is similarly calculated (Davis, 1973, p. 292) and the mutual substitutability is simply the product of the left and right substitutabilities. Cluster analysis can be applied to the matrix of substitutabilities to illustrate groupings.

III. Procedure

The definition of cyclicity employed in this study is the "cyclicity of sequence" of Schwarzacher (1969, p. 18). Only the sequence and not the thickness of individual rock units is considered in this definition, and thus the masking effect of differential sedimentation rates is eliminated, as discussed previously.

The Mount Allan section of the Kootenay Formation was analyzed using auto-association at classification levels recognizing 26, 11 and 6 lithotypes. To minimize the effect of non-stationarity in the section, the character string representing the section was segmented into shorter strings or intervals, each with 75 transitions, at

classification levels recognizing 26 and 11 lithotypes. These intervals were then individually analysed by auto-association. Auto-association recognizing 6 lithotypes was carried out on the same intervals used for 11 lithotypes. In addition, the three pairs of lithotypes with the highest mutual substitutabilities in each of the intervals at a classification level recognizing 26 lithotypes, and the two pairs with the highest mutual substitutabilities recognizing 11 lithotypes, were combined as shown in Tables 5 and 6, and auto-association was again performed. In this way the effect of the classification level recognized, and the presence of lithologic interchangeability could be assessed.

The computer program used to perform auto-association is the same as that used for cross-association in chapter 5, modified to include the binomial mean number of matches for a random chain compared to itself. The random binomial mean is derived from the formula (Davis, 1973, p. 255):

$$Pr = \sum_{k=1}^{m} X_k^2 - n \ / \ n^2 - n$$

where: Pr times the number of comparisons = random binomial mean

m = number of states

X_k = number of observations of k^{th} state

n = total number of observations

The statistics provided as output from the program are the same as those discussed for cross-association in chapter 5. The distance from the random binomial mean, in units of standard deviation, was used as a measure of the auto-association of a series at a given lag, and plotted against lag as a graphic display of the auto-association of

Table 5 - Lithotypes Combined Using Mutual Substitutability by Interval - Mount Allan Section Recognizing 26 Lithotypes*

Interval	Depth in feet from top of Mount Allan Section	Lithotypes Combined	New Lithotype Code	Mutual Substitutability
1	0 - 372	6,18	A1	.3333
		17,15	B1	.2981
		16,26	C1	.2795
2	372 - 730	26,21	A2	.2542
		14,7	B2	.2279
		25,22	C2	.1929
3	730 - 1080	19,2	A3	.5000
		25,24	B3	.3536
		18,4	C3	.3070
4	1080 - 1366	25,24	A4	1.0000
		11,22	B4	.7071
		19,1	C4	.5774
5	1366 - 1670	8,7	A5	.5774
		12,6	B5	.3354
		10,18	C5	.3070
6	1670 - 1960	4,2	A6	.6251
		14,2	B6	.5774
		6,21	C6	.4781
7	1960 - 2222	25,22	A7	1.0000
		4,3	B7	.4459
		10,2	C7	.3651
8	2222 - 2476	6,4	A8	.4386
		19,3	B8	.3883
		9,2	C8	.2767
9	2476 - 2752	7,4	A9	.5000
		14,2	B9	.3371
		11,2		.3354
10	2752 - 3040	3,1	A10	.4009
		18,14	B10	.4433
		12,14		.3849
11	3040 - 3398	20,9	A11	.4792
		14,9		.3622
		13,4	B11	.3333
12	3398 - 3864	9,22	A12	.4286
		14,8	B12	.3266
		20,18	C12	.3158

* Lithotype codes are as they are given in chapter 4

Table 6 - Lithotypes Combined Using Mutual Substitutability by Interval - Mount Allan Section Recognizing 11 Lithotypes*

Interval	Depth in feet from top of Mount Allan Section	Lithotypes Combined	New Lithotype Code	Mutual Substitutability
1	0 - 420	7,6	A1	.4087
		11,8	B1	.3554
2	420 - 806	2,1	A2	.3989
		10,8	B2	.2925
3	806 - 1188	4,7	A3	.8044
		6,2	B3	.6485
4	1188 - 1482	1,2	A4	.7127
		5,6	B4	.5767
5	1482 - 1830	5,2	A5	.8184
		6,2		.7904
6	1830 - 2134	1,6	A6	.7933
		5,6		.7134
7	2134 - 2430	1,4	A7	.6153
		5,4		.5313
8	2430 - 2762	7,1	A8	.6317
		6,1		.6241
9	2762 - 3168	4,7	A9	.4825
		1,7		.4477
10	3168 - 3562	5,2	A10	.7391
		4,8	B10	.5022
11	3562 - 3864	5,8	A11	.6317
		2,8		.5767

* Lithotype codes are as they appear in Figure 7.

each interval. Intervals were then scanned manually to determine the components of any cycles indicated from these plots.

IV. Results

Auto-association plots for the intervals and classification levels discussed above appear in Appendix D. No consistently high auto-associations at intervals of greater than two match positions or lags are evident in any of these plots, indicating the absence of cycles with a period longer than two transitions. The two-step oscillatory nature of these plots becomes progressively more evident as the classification level is simplified. Two-state "cycles" which occur two or more times within intervals examined are given in Tables 7 to 11. An idea of the relative significance of each of these cycles can be obtained by comparing the number of occurrences with the expected number of occurrences in a random series with the same frequency of occurrence of lithotypes as the interval examined. The expected number of occurrences in a random series was calculated using the formula:

$$E = \frac{Nm^2 . Np}{n^2}$$

where: E = expected number of occurrences of cycle m-p-m

n = number of lithotypes in interval

Nm = number of occurrences of lithotype m, where m is the initial lithotype in the cycle.

Np = number of occurrences of lithotype p.

No two-state cycles of importance are evident at a classification level recognizing 26 lithotypes. Alternations between coarse sandstone and conglomerate (lithotypes 22 and 25) and fine sandstone and siltstone (lithotypes 14 and 7) are evident after mutual substitutability, as are less frequent alternations between coarse sandstone and

claystone (lithotypes 18 and 4) and siltstone (lithotype 9) (Tables 7 and 10).

Frequent alternations between fine sandstone lithotype 6 and siltstone lithotype 4 are evident at a classification level recognizing 11 lithotypes. Alternations of lesser frequency between fine sandstone lithotype 6 and claystone lithotype 1 are also evident. Alternations between fine sand, siltstone and claystone lithotypes are more numerous and alternations between coarse sand and conglomerate (lithotypes 8 and 10) and coarse sand lithotype 9 are evident after mutual substitutability at this classification level (Tables 8 and 11).

Alternations between fine sand and siltstone are frequent at a classification level recognizing 6 lithotypes as are alternations between fine sandstone and claystone. Less frequent alternations between fine sand and coarse sand, and coarse sand and conglomerate are also evident (Table 9).

It is difficult to relate the existence of the two-state "cycles" to cyclic elements within their depositional environment, other than to say they are primarily a result of alternations between high and low energy fluviatile environments with resulting alternations between fine and coarse sediment. Had the thickness of the component lithologic units been taken into account, inference as to the relative duration and nature of these regimes and the time represented by each "cycle" would have been possible, however, as the "cycles" are generally separated by apparently random sequences of sediment and are only rarely consecutive, cyclic phenomena appear to have had little control on the deposition of the Kootenay Formation as a whole.

Table 7 - Two-State Cycles Observed Recognizing
26 Lithotypes - Mount Allan Section*

Two State Cycles Observed	Number	Probable Number in Random Series
9-4-9	2	.571
9-6-9	2	.719

* Lithotype codes are as they are given in chapter 4.

Table 8 - Two-State Cycles Observed Recognizing
11 Lithotypes - Mount Allan Section*

Two State Cycles Observed	Number	Probable Number in Random Series
4-6-4	22	6.73
6-4-6	14	6.06
4-1-4	11	4.29
1-4-1	5	2.46
7-8-7	5	1.61
4-5-4	5	4.11
4-2-4	5	2.41
8-7-8	4	.32
5-1-5	4	1.29
6-1-6	3	3.48
7-6-7	3	1.45
1-5-1	3	1.35
6-7-6	3	2.82
10-9-10	2	.01
5-4-5	2	2.26
8-9-8	2	.08
11-10-11	2	.0002
10-11-10	2	.0014

* Lithotype codes are as they appear in Figure 7.

Table 9 - Two-State Cycles Observed Recognizing
6 Lithotypes - Mount Allan Section*

Two-State Cycles Observed	Number	Probable Number in Random Series
3-4-3	47	17.98
4-3-4	40	16.05
3-1-3	39	13.17
1-3-1	30	8.61
4-1-4	8	10.49
4-5-4	7	3.92
1-4-1	6	7.68
3-2-3	5	2.95
5-4-5	5	1.07
5-6-5	5	.09
6-5-6	4	.03
2-3-2	2	.43

* Lithotype codes are as they appear in Figure 7.

Table 10 - Two-State Cycles Observed by Interval after Mutual Substitutability Recognizing 26 Lithotypes*

Interval	Two-State Cycles Observed	Number	Probable Number in Random Series
1	-	-	-
2	B2-C2-B2	6	.272
	C2-B2-C2	4	.272
3	C3-9-C3	4	.294
	9-C3-9	3	.168
	21-B3-21	2	.012
	B3-21-B3	2	.012
	11-A3-11	2	.009
4	9-6-9	2	.174
5	21-A5-21	2	.058
	A5-21-A5	2	.074
	14-3-14	2	.111
6	A6-9-A6	4	.694
	B6-9-B6	2	.309
7	-	-	-
8	B8-A8-B8	2	.360
	A8-B8-A8	2	.333
9	B9-1-B9	2	.288
	B9-9-B9	2	.336
10	B10-A10-B10	2	.813
11	A11-6-A11	3	.204
12	-	-	-

* Lithotype codes and intervals are as they are given in Table 5 and Figure 7 recognizing 26 lithotypes.

Table 11- Two-State Cycles Observed by Interval after Mutual Substitutability Recognizing 11 Lithotypes*

Interval	Two-State Cycles Observed	Number	Probable Number in Random Series
1	9-B1-9	3	.052
	B1-9-B1	3	.114
	2-4-2	2	.076
2	B2-9-B2	5	.207
	9-B2-9	3	.170
	5-A2-5	2	.321
3	B3-A3-B3	11	2.012
	A3-B3-A3	9	2.204
4	4-B4-4	3	1.253
	B4-A4-B4	3	.857
	A4-B4-A4	2	.586
	7-B4-7	2	.500
	B4-4-B4	2	1.253
	7-8-7	2	.131
	4-A4-4	2	.857
	A4-4-A4	2	.586
5	A5-4-A5	12	2.704
	4-A5-4	11	2.591
6	A6-4-A6	15	3.967
	4-A6-4	14	4.126
7	A7-6-A7	11	2.504
	6-A7-6	8	2.178
8	4-A8-4	9	2.228
	A8-4-A8	8	2.785
	5-A8-5	2	.674
	A8-5-A8	2	1.532
9	A9-6-A9	10	2.420
	6-A9-6	7	1.980
	A9-3-A9	3	1.076
10	7-B10-7	3	.592
	B10-7-B10	2	.719
	6-A10-6	2	.546
	A10-6-A10	2	.410
11	A11-6-A11	4	.853
	6-A11-6	3	.853

* Lithotype codes and intervals are as they are given in Table 6 and Figure 7 recognizing 11 lithotypes.

V. Conclusions

Cyclic phenomena of the type observed in the Pennsylvanian coal measures of the eastern United States are not apparent in rocks of the Kootenay Formation. Cyclic environmental elements which may have been responsible for the two-state alternations of lithotypes observed within the Kootenay have not played a major role in the deposition of the formation as a whole.

The environmental synthesis of Jansa (1972) which attributed deposition of the Kootenay and upper Fernie Formations and the basal Blairmore Group to a northeasterly prograding delta system allows for the temporary recurrence of a given environment, but does not require an orderly and repetitive succession of environments, and thus appears to be a satisfactory depositional model.

Investigations into the structure of transition probability matrices derived from the Kootenay Formation, may give further insights into its depositional mechanisms. In order to maximize the significance of such matrices, and minimize the effect of non-stationarity, the number of states recognized and the length of segments analyzed should be small.

Chapter 7

Summary and Conclusions

This study involved correlation within the Kootenay Formation and basal Blairmore Group of the Cascade Coal Basin, and an attempt to detect cyclic lithologic repetitions within a complete section of the Kootenay Formation exposed on Mount Allan.

Correlation between the Mount Allan, Wind Ridge and Three Sisters sections of the Kootenay Formation was approached using two methods. The first entailed the use of only grain size data and the technique of cross-correlation. The second employed rock types derived by cluster analysis and the technique of cross-association. The second method was carried out three times, each time employing a classification scheme in which fewer rock types were recognized. Broad agreement was observed between the two methods.

The best correlation between the Wind Ridge and Mount Allan sections occurs when the base of the Wind Ridge section is between 440 to 550 feet below the top of the Mount Allan section. If this is the case, conglomerates on Wind Ridge should be included in the Blairmore Group and not the Kootenay Formation as has been the interpretation of several previous authors (Crockford, 1949; Norris, 1958; Price, 1970).

The best correlation between the Three Sisters and Mount Allan sections occurs when the base of the Three Sisters section is 3150 feet below the top of the Mount Allan section. Here the best correlations are given by cross-association recognizing 11 and 6 rock types, and by cross-correlation. This is apparently due to lateral facies changes within this part of the formation over the ten miles

separating the two sections. These facies changes are reflected in the classification scheme recognizing 26 rock types, but are lost in the classification schemes recognizing 11 and 6 rock types.

An attempt to detect cyclic lithologic repetitions in the Mount Allan section of the Kootenay Formation was approached using the techniques of auto-association and substitutability analysis. Auto-association was performed on intervals of the section using the three rock type classification schemes derived by cluster analysis. In addition, three pairs of rock types were combined at a classification level recognizing 26 rock types, and two pairs of rock types were combined at a classification level recognizing 11 rock types, according to their tendency to be preceded and followed by common rock types or mutual substitutability, in an attempt to clarify any cyclicity present but obscured by lithologic "substitutions". Auto-association was then again performed on these intervals.

Only the sequence and not the thickness of rock units was considered. The only "cycles" evident from the analysis were two-state alternations between rock types. The cyclic environmental elements responsible for deposition of these two-state cycles are not considered to have had a major role in the deposition of the Kootenay Formation as a whole, as these two-state cycles are generally separated by apparently random sediment sequences, and are only rarely consecutive. Most of these two-state cycles involve alternations between fine sandstone and claystone, fine sandstone and coarse sandstone, and coarse sandstone and conglomerate.

Further insights into the depositional mechanisms of the Kootenay Formation might be gained by analyzing the structure of

transition probability matrices derived from the data used in this study. These matrices could be tested for the presence of the Markov property, and the transition, recurrence and first-passage probabilities of their elements could be examined. In this way cycles which may have been obscured by the methodology employed in this study may become apparent. Such transition probability matrices must be derived from small segments of the section in order to minimize the effect of the overall environmental change observed in the formation, and should differentiate few rock types in order to maximize the number of transitions between rock types and the resulting statistical significance of these matrices.

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Appendix A - Measured Section Descriptions

MOUNT ALLAN SECTION

Location - Segment 1 - measured on ridge at the summit of Mount Allan in Section 21, Township 23, Range 9, West of the 5th Meridian.

Unit No.	Description	Thickness (Feet)	Feet Above Base
	Blairmore Group (Gladstone Formation)		
11-001	Sandstone with minor conglomerate; sandstone is calcareous, medium to very coarse grained, dark brown to grey, light brown weathering, cross-bedded, and becomes coarser grained near base; 10% of unit is a sandy conglomerate which occurs at base; unit is thin to medium bedded, resistant, and has a sharp, conformable lower contact.	10.4	209.4
11-002	Siltstone; noncalcareous, grey to light grey, light grey weathering, iron staining and pyrite present; unit is very thinly bedded, recessive, and has a gradational lower contact.	1.2	199.0
11-003	Siltstone and minor claystone; siltstone is calcareous, sandy in part, very hard, dark grey to grey, rusty brown weathering; 10% of unit is silty claystone which occurs in middle; iron staining and pyrite present; unit is thin to medium bedded and moderately resistant.	11.9	197.8
	Covered	12.4	185.9
11-004	Siltstone; slightly calcareous, dark grey, rusty brown weathering; unit is thin to medium bedded, recessive, mostly covered, and has a gradational lower contact.	1.6	173.5
11-005	Sandstone, calcareous, medium grained, grey, red brown to brown weathering, cross-bedded; unit is thin bedded, moderately resistant.	3.8	171.9
	Covered	2.1	168.1
11-006	Siltstone and sandstone; siltstone is calcareous, dark grey, light brown to grey weathering; lower four feet is very fine grained sandstone calcareous, dark brown, light brown weathering, cross-laminated; unit is thin bedded and moderately resistant.	8.6	166.0
	Covered	8.6	157.4
11-007	Sandstone; very fine to fine grained, dark grey to brown weathering; unit is medium bedded, moderately resistant and has a gradational lower contact.	2.0	148.8

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-008	Sandstone; fine to medium grained grading to medium grained at base, dark grey, dark brown to brown weathering, cross-laminated; unit is thin bedded and moderately resistant.	3.6	146.8
	Covered	7.6	143.2
11-009	Sandstone; calcareous, very hard, very fine grained dark grey, red brown weathering; unit is thin bedded and moderately resistant.	1.4	135.6
	Covered	12.9	134.2
11-010	Sandstone and Siltstone; sandstone is calcareous, fine to medium grained, dark grey, light grey weathering, grades to siltstone at top of unit; siltstone is grey and yellow brown weathering; unit is medium bedded and moderately resistant.	7.9	121.3
	Covered	2.1	113.4
11-011	Sandstone interbedded with minor claystone; siltstone is calcareous, very fine to fine grained, silty, dark grey, light grey to yellow weathering; claystone is dark grey, weathers rusty brown and occurs as interbeds near base of unit; unit is thin bedded, moderately resistant and has a gradational lower contact.	9.4	111.3
11-012	Sandstone; calcareous, very fine grained grading to fine and medium grained at base, dark grey to grey brown, light brown grey weathering, cross-laminated; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	8.9	101.9
11-013	Sandstone with minor conglomerate; sandstone is coarse grained and becomes pebbly near base, dark grey to grey, red brown to brown weathering; 20% of unit is conglomerate which occurs at base, is dark grey and weathers dark brown; unit is thick to very thick bedded, resistant and has a sharp, conformable lower contact.	10.2	93.0
11-014	Sandstone; calcareous, medium to coarse grained, grading to fine grained at top, grey, light brown to grey weathering, cross-bedded; unit is thin bedded, moderately resistant and has a gradational lower contact.	5.8	82.8
11-015	Sandstone and conglomerate; sandstone is calcareous, coarse to very coarse grained and pebbly, grey, rusty brown weathering, cross-bedded; 60% of the unit is a chert clast conglomerate which occurs in lower half and as interbeds in upper part of the unit, mean clast size is 3 centimeters in diameter, the conglomerate is grey and weathers rusty brown; unit is very thick bedded and has	10.2	77.0

Unit No.	Description	Thickness (Feet)	Feet Above Base
	a sharp, locally disconformable lower contact.		
11-016	Siltstone interbedded with claystone; siltstone is noncalcareous, dark grey, dark brown to grey weathering; claystone is black and weathers dark grey; thin bed of pebbly siltstone occurs near base; unit is very thin to medium bedded, lower contact is sharp and conformable.	16.8	66.8
11-017	Conglomerate; quartzite clasts up to 16 centimeters in diameter, average clast size about 10 to 12 centimeters decreasing to 3 centimeters in diameter near top of unit and 6 centimeters in diameter near base, 60% of clasts are well rounded white quartzite, the remainder are mainly black grey and green chert conglomerate is light brown to grey and weathers dark brown; minor lenticular coarse grained sandstone beds occur dispersed within the conglomerate; unit is resistant, very thick bedded and has a gradational lower contact.	35.0	50.0
11-018	Conglomerate; contains a higher proportion of quartz pebbles than unit 11-017, average pebble size is 1 to 2 centimeters in diameter, grades to medium grained sandstone at base, light grey, weathers brown to light brown, cross-bedded; unit is medium bedded, resistant and has a sharp conformable lower contact.	3.2	15.0
11-019	Conglomerate interbedded with minor sandstone; conglomerate is brown to grey, red brown to brown weathering, average clast size is 2 centimeters in diameter; sandstone is medium to coarse grained, light brown to grey and weathers red brown; unit is very thick bedded and sits on a recessive, mostly covered interval, the lower contact is disconformable.	11.8	11.8
	Base of Blairmore Group		
	Total Thickness of Blairmore Strata Measured		209.4
	Kootenay Formation (Upper Conglomeratic Unit)		
	Covered	1.4	3801.2
11-020	Sandstone with minor conglomerate; sandstone is noncalcareous, medium to very coarse grained, grey, light grey to brown weathering; chert clast conglomerate occurs as interbeds, clasts are mainly black chert with minor grade chert and minor quartzite, conglomerate has high proportion of matrix, average clast size is 1 to 2 centimeters in diameter; unit is medium to thick bedded, resistant and has a gradational lower contact.	31.6	3799.8

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-021	Conglomerate with minor sandstone; conglomerate is grey, weathers dark grey to grey, clasts are composed mainly of chert and average about 2 centimeters in diameter; sandstone is coarse grained, light grey, light red brown to grey weathering, occurs as interbeds in lower and middle part of unit; unit is thick to very thick bedded, resistant and has a sharp, conformable lower contact.	11.0	3768.2
11-022	Claystone; very calcareous, silty in part, dark grey, purple to rusty brown weathering; unit is very thin to thin bedded, recessive and has a sharp lower contact.	11.2	3757.2
11-023	Claystone; calcareous, silty in part, dark grey, rusty brown weathering; unit is medium bedded, somewhat more resistant than unit 11-022 and has a gradational lower contact.	19.6	3746.0
11-024	Sandstone; silty in part, very fine to fine grained, dark grey, light grey to brown weathering; unit is medium bedded, moderately resistant and has a gradational lower contact.	2.5	3726.4
11-025	Sandstone; calcareous, medium grained grading to very coarse grained and pebbly near base, grey, rusty brown to grey weathering, minor cross-bedding; unit is medium to thick bedded, resistant and has a gradational lower contact.	6.3	3723.9
11-026	Conglomerate; clasts are mainly black chert and average about 2 centimeters in diameter, grey, light red brown weathering; unit is thick bedded, resistant and has a sharp conformable lower contact.	3.6	3717.6
11-027	Sandstone; fine to medium grained, light grey, grey brown weathering, massive; unit is medium bedded, resistant and has a gradational lower contact.	2.3	3714.0
11-028	Sandstone interbedded with conglomerate; sandstone is coarse to very coarse grained and pebbly, grey, red brown to grey weathering, grades down into chert clast conglomerate near base; conglomerate is light grey to grey, red brown to grey weathering, clasts are mainly black chert and average 2 to 3 centimeters in diameter at base of unit and one centimeter in diameter above base; unit is medium to very thick bedded, resistant and has a sharp conformable lower contact.	11.2	3711.7
11-029	Sandstone; fine to medium grained, light grey, light grey to brown weathering, massive; unit is thin bedded, moderately resistant and has a sharp conformable lower contact.	1.6	3700.5
11-030	Conglomerate with minor sandstone; conglomerate is grey to dark grey, red brown to grey weathering, clasts are mainly black chert with minor quartzite	9.6	3698.9

Unit No.	Description	Thickness (Feet)	Feet Above Base
	and green chert and average 3 centimeters in diameter; sandstone is medium grained, grey, light grey weathering, cross-laminated and occurs in a 1 foot thick bed in the middle of the unit; unit is very thick bedded and resistant.		
	Covered	7.7	3689.3
11-031	Claystone; calcareous, dark grey, rusty brown to scarlet weathering; unit is thin bedded and moderately recessive.	4.7	3681.6
	Covered	3.9	3676.9
11-032	Sandstone and siltstone; sandstone is slightly calcareous, very fine to fine grained, dark grey, dark brown weathering, cross-laminated; siltstone is calcareous, dark grey, dark grey weathering and occurs near the top and bottom of the unit; unit is medium to thick bedded and moderately resistant.	8.7	3673.0
	Covered	4.2	3664.3
11-033	Claystone; silty, dark grey, light brown to scarlet weathering; unit is thin to medium bedded, moderately recessive and has a gradational lower contact.	5.9	3660.1
11-034	Claystone; dark grey to grey, scarlet weathering; unit is laminated, recessive and has a gradational lower contact.	4.5	3654.2
11-035	Claystone; silty in part, dark grey, brown to scarlet weathering; unit is thin to medium bedded moderately recessive and has a gradational lower contact.	6.6	3649.7
11-036	Claystone; dark grey, scarlet weathering; unit is very thin to thin bedded, recessive and has a gradational lower contact.	6.6	3643.1
11-037	Claystone; slightly calcareous, silty in part, dark grey, grey to brown weathering, unit is medium bedded, moderately resistant and has a gradational lower contact.	2.4	3636.5
11-038	Claystone; dark grey, red brown weathering; unit is laminated, recessive and has a sharp lower contact.	6.6	3634.1
11-039	Claystone and siltstone; claystone is slightly calcareous, grey, and dark grey to brown weathering; siltstone is sandy, dark grey, rusty brown to brown weathering and occurs as interbeds at the top and bottom of the unit; the unit is very thinly bedded, moderately recessive and has a sharp conformable lower contact.	13.8	3627.5
11-040	Claystone; dark grey, dark grey to rusty brown	10.0	3613.7

Unit No.	Description	Thickness (Feet)	Feet Above Base
	weathering; unit is laminated to very thinly bedded, recessive and has a sharp conformable lower contact.		
11-041	Siltstone; dark grey, red brown weathering; unit is thin bedded, moderately recessive and has a sharp conformable lower contact.	2.0	3603.7
11-042	Claystone; grey, grey weathering; unit is very thinly bedded and recessive.	9.4	3601.7
11-043	Siltstone; calcareous, sandy, grey, rusty brown weathering, cross-laminated; unit is medium bedded, moderately resistant and has a sharp conformable lower contact.	3.6	3592.3
11-044	Claystone; silty, dark grey, dark grey to red brown weathering; unit is very thin to medium bedded, moderately recessive and has a sharp conformable lower contact.	7.9	3588.7
11-045	Siltstone and claystone; siltstone is grey to rusty brown weathering; claystone is carbonaceous, dark grey, grey weathering and occurs as interbeds and at base of unit; unit is medium bedded, moderately resistant and has a sharp conformable lower contact.	10.3	3580.8
11-046	Claystone; dark grey, dark grey to rusty brown weathering; unit is laminated to thinly bedded and has a sharp conformable lower contact.	6.2	3570.5
11-047	Siltstone with minor claystone; siltstone is grey and rusty brown weathering; claystone is dark grey, dark grey weathering and occurs at top of unit; unit is medium to thick bedded, moderately resistant and has a sharp conformable lower contact.	5.9	3564.3
11-048	Claystone; dark grey and dark grey to rusty brown weathering; unit is laminated to very thinly bedded, moderately recessive and has a sharp conformable lower contact.	4.3	3558.4
11-049	Siltstone and claystone; siltstone is dark grey and weathers brown; claystone is dark grey, dark grey to grey weathering and occurs near middle of unit, unit is medium bedded and moderately resistant.	5.0	3554.1
	Covered	11.0	3549.1
11-050	Siltstone and claystone; siltstone is dark grey and weathers dark red brown to yellow brown; claystone is grey, yellow brown to grey weathering and occurs near middle of unit; unit is very thin to medium bedded and moderately resistant.	5.6	3538.1

Unit No.	Description	Thickness (Feet)	Feet Above Base
	Covered	5.0	3532.5
11-051	Sandstone and siltstone; sandstone is calcareous, very fine to fine grained, dark grey, yellow brown weathering, cross-laminated; siltstone is calcareous, dark grey, yellow brown to rusty brown weathering and occurs near top of unit; unit is medium bedded, moderately resistant and has a gradational lower contact.	6.2	3527.5
11-052	Claystone; dark grey, dark grey weathering; unit is laminated, recessive and has a gradational lower contact.	4.0	3521.3
11-053	Claystone; silty, grey, red brown weathering; unit is medium bedded, moderately recessive and has a sharp conformable lower contact.	3.2	3517.3
11-054	Claystone; calcareous, dark grey, grey to dark brown weathering; unit is very thinly to thinly bedded, recessive, becomes silty and more resistant near base and has a gradational lower contact.	19.0	3514.1
11-055	Sandstone; slightly calcareous in part, fine to medium grained, dark grey, red brown to brown weathering, cross-laminated; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	6.5	3495.1
11-056	Sandstone; slightly calcareous, medium grained grading to coarse and very coarse grained at base, grey brown, grey weathering, cross-bedded; unit is medium to thick bedded, resistant, structurally deformed and has a sharp disconformable lower contact.	29.5	3488.6
11-057	Sandstone and siltstone; sandstone is calcareous, very fine to fine grained, dark grey, light brown weathering, cross-laminated; siltstone is calcareous, dark grey, grey to light brown weathering and occurs near top of unit; unit is laminated to very thinly bedded, moderately resistant and has a gradational lower contact.	5.1	3459.1
11-058	Sandstone interbedded with minor conglomerate; sandstone is calcareous, coarse to very coarse grained, dark grey, grey to light brown weathering, cross-bedded; conglomerate is dark grey, grey weathering and occurs in lower part of unit, clast composition is predominantly black chert with minor white chert and quartzite, clasts average 1 centimeter in diameter; unit is medium to thick bedded, resistant and has a gradational lower contact.	18.0	3454.0

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-059	Conglomerate interbedded with minor sandstone; conglomerate is dark grey and weathers grey brown, clast composition is predominantly black chert with minor white chert and quartzite, clasts are well rounded and have an average diameter of 2 centimeters, some quartzite clasts near base are up to 8 centimeters in diameter; sandstone is calcareous, very coarse grained, grey, grey to light brown weathering, cross-bedded and occurs as interbeds throughout the unit; unit is thick to very thick bedded and has a sharp disconformable lower contact.	20.0	3436.0
11-060	Sandstone; calcareous, medium grained, dark grey, grey to light brown weathering; unit is medium bedded, moderately resistant and has a gradational lower contact.	2.0	3416.0
11-061	Conglomerate; sandy in part, grey, brown to grey weathering, clast composition is predominantly black chert, average clast diameter is about 3 centimeters and ranges up to 8 centimeters; unit is very thick bedded, resistant.	11.5	3414.0
	Base of Upper Conglomeratic Unit		
	End of Segment 1		
	Mount Allan - Segment 2 - measured on northeast face of Mount Allan in Section 21, Township 23, Range 9, West of the 5th Meridian.		
	Covered	9.0	3402.5
11-062	Siltstone; calcareous, sandy, dark grey, dark grey to brown weathering, cross-laminated; minor conglomerate near base of unit, unit is laminated to thinly bedded, moderately resistant and has a gradational lower contact.	13.8	3393.5
11-063	Sandstone; calcareous, medium grained, dark grey to grey, light grey weathering, cross-laminated; unit is medium bedded, moderately resistant and has a gradational lower contact.	3.5	3379.7
11-064	Sandstone with minor conglomerate; sandstone is calcareous, coarse to very coarse grained, dark grey, grey weathering, cross-bedded; conglomerate is dark grey, weathers grey, clasts are predominantly black chert and average less than 1 centimeter in diameter, conglomerate occurs at base of unit; unit is medium bedded, resistant and has a sharp conformable lower contact.	10.7	3376.2
11-065	Sandstone; calcareous, medium to coarse grained, grading to very coarse grained and pebbly at	15.3	3365.5

Unit No.	Description	Thickness (Feet)	Feet Above Base
	base, dark grey, grey weathering, cross-bedded; unit is thin to medium bedded, resistant and has a sharp conformable lower contact.		
11-066	Siltstone and sandstone; siltstone is calcareous, dark grey, grey weathering; sandstone is calcareous, very fine to fine grained, dark grey, grey weathering and occurs at base of unit; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	6.8	3350.2
11-067	Sandstone; calcareous, medium grained near top grading to coarse and very coarse grained and pebbly near base, dark grey, grey to grey brown weathering, cross-bedded; unit is medium bedded, resistant and has a sharp conformable lower contact.	5.8	3343.4
11-068	Siltstone; calcareous, dark grey, dark grey to brown weathering, contorted bedding; unit is very thin to thin bedded, moderately resistant and has a sharp conformable lower contact.	2.5	3337.6
11-069	Sandstone; calcareous, medium grained, light grey, light brown weathering, cross-bedded; unit is medium bedded, moderately resistant and has a sharp conformable lower contact.	4.8	3335.1
11-070	Claystone with minor siltstone; claystone is silty in part, dark grey, yellow brown weathering; siltstone is carbonaceous in part, dark grey, brown weathering and occurs at base of unit; unit is medium bedded, recessive and has a gradational lower contact.	7.2	3330.3
11-071	Sandstone; calcareous, fine grained grading to medium grained near base, grey to dark brown, grey weathering, cross-laminated; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	7.5	3323.1
11-072	Siltstone and sandstone; siltstone is dark grey, grey to brown weathering and becomes sandy near base; sandstone is medium to coarse grained, dark grey, grey to red brown weathering, cross-laminated; unit is very thin to medium bedded, moderately resistant and has a sharp conformable lower contact.	12.0	3315.6
11-073	Claystone; calcareous, silty near base, light grey, light brown to yellow weathering, cross-laminated, bedding contorted near top; unit is laminated at top and thinly bedded at base, moderately resistant and has a gradational lower contact.	5.3	3303.6
11-074	Siltstone; carbonaceous near top, dark grey, light grey to brown weathering, very hard; unit is medium bedded, moderately resistant and has gradational lower contact.	1.6	3298.3

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-075	Siltstone; carbonaceous partings and minor silty claystone interbeds near base, dark grey, dark brown weathering, cross-laminated near top; unit is medium to thick bedded, moderately resistant and has a gradational lower contact.	14.9	3296.7
11-076	Sandstone; calcareous, very fine to fine grained, dark brown, light brown weathering, cross-laminated; unit is medium to thick bedded, resistant and has a gradational lower contact.	3.5	3281.8
11-077	Claystone; calcareous, dark grey, brown to yellow weathering near top, dark grey weathering near base; unit is very thin to thin bedded, recessive and has a sharp conformable lower contact.	4.6	3278.3
11-078	Sandstone; calcareous near top, fine to medium grained, dark grey to grey, light brown weathering, cross-laminated near top and bottom; unit is thin to medium bedded, moderately resistant and has a sharp conformable lower contact.	7.2	3273.7
11-079	Claystone; carbonaceous, dark grey, dark grey weathering; unit is very thinly bedded, recessive and has a gradational lower contact.	3.0	3266.5
11-080	Claystone; calcareous in middle and top of unit, silt near top, carbonaceous near base, dark grey, rusty brown to yellow weathering; unit is laminated to thinly bedded and moderately recessive.	3.9	3263.5
	Covered	8.5	3259.6
11-081	Siltstone; calcareous and sandy in part, dark grey, grey to brown weathering, cross-laminated in part, carbonaceous partings near base, ripple marks evident on some bedding surfaces; unit is medium bedded, moderately resistant and has a gradational lower contact.	17.6	3251.1
11-082	Claystone; calcareous, dark grey, grey to brown weathering, plant remains evident; unit is thin bedded, recessive and has a gradational lower contact.	6.1	3233.5
11-083	Siltstone; calcareous, carbonaceous near base, sandy near top, dark grey, grey to brown weathering, plant remains evident near base, cross-laminated in part; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	2.6	3227.4
11-084	Claystone; calcareous, dark grey, dark grey to brown weathering, carbonaceous, abundant plant remains; unit is thinly laminated, recessive and has a gradational lower contact.	2.5	3224.8
11-085	Claystone; silty, calcareous, dark grey, yellow brown weathering; unit is very thin to thin bedded, moderately recessive and has a sharp conformable	5.0	3222.3

Unit No.	Description	Thickness (Feet)	Feet Above Base
	lower contact.		
	Covered	4.0	3217.3
11-086	Siltstone; dark grey, grey weathering, very hard and massive; unit is medium bedded, moderately resistant and has a sharp conformable lower contact.	1.4	3213.3
11-087	Siltstone with minor sandstone; siltstone is calcareous, dark grey, yellow brown weathering, cross-laminated; sandstone is calcareous, very fine grained, dark grey, grey to yellow brown weathering, cross-laminated and occurs at top of unit; unit is thin bedded, moderately resistant and has a sharp conformable lower contact.	10.3	3211.9
11-088	Siltstone with minor sandstone; siltstone is sandy near base, dark grey to grey, light grey weathering; sandstone is very fine grained, light grey weathering and occurs at base of unit; some silty claystone occurs as interbeds throughout the unit; unit is medium bedded, moderately resistant and has a sharp conformable lower contact.	5.3	3201.6
11-089	Sandstone; calcareous, fine to medium grained, grey to dark brown, light grey to brown weathering, cross-bedded; unit is thin to medium bedded, resistant and has a sharp conformable lower contact.	10.9	3196.3
11-090	Sandstone; calcareous, very fine to fine grained, dark grey, light brown weathering, cross-laminated near top; unit is very thin to medium bedded, resistant and has a sharp disconformable lower contact.	12.5	3185.4
11-091	Conglomerate; poorly cemented, clasts average less than 1 centimeter in diameter, dark grey, red brown weathering; unit is thin bedded and moderately recessive.	1.2	3172.9
	Covered	1.6	3171.7
11-092	Claystone with minor siltstone; claystone is calcareous, silty, dark grey, grey brown weathering, cross-laminated; siltstone is dark grey, grey brown weathering, cross-laminated and occurs near base of unit; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	8.7	3170.1
11-093	Sandstone; calcareous, very fine to fine grained, dark grey, brown to grey weathering, cross-laminated; unit is medium bedded, resistant and has a gradational lower contact.	3.0	3161.4
11-094	Siltstone; calcareous, sandy near base, dark grey, grey weathering; unit is thin bedded, moderately resistant and has a gradational lower contact.	3.7	3158.4

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-095	Sandstone; calcareous, is very fine grained, dark grey, light grey to brown weathering, cross-laminated; unit is thin bedded, moderately resistant and has a gradational lower contact.	3.1	3154.7
11-096	Sandstone; calcareous, medium to coarse grained, minor pebbly sandstone interbeds near base, dark grey, light brown to brown weathering, cross-bedded; unit is medium to very thick bedded and has a gradational lower contact.	41.4	3151.6
11-097	Conglomerate interbedded with minor sandstone; conglomerate is dark grey, grey weathering, clasts range up to 5 centimeters in diameter and average about 3 centimeters, clasts are composed mainly of black chert and minor white quartzite; sandstone is calcareous, coarse to very coarse grained, dark grey, grey weathering; unit is thick bedded, resistant and has a sharp disconformable lower contact.	7.1	3110.2
11-098	Claystone and minor coal; claystone is dark grey, rusty brown to black weathering; coal occurs in a 15 centimeter thick seam at top of unit; unit is very thin bedded, recessive, and has a sharp conformable lower contact.	5.0	3103.1
11-099	Siltstone; calcareous, dark grey, light brown to yellow weathering, cross-laminated; unit is thin bedded, moderately resistant and has a gradational lower contact.	2.2	3098.1
11-100	Claystone; calcareous, silty, dark grey, light grey to brown weathering, carbonaceous partings and plant remains evident; unit is thinly laminated to very thin bedded, recessive and has a gradational lower contact.	1.9	3095.9
11-101	Siltstone and sandstone; siltstone is calcareous, dark grey, light brown to brown weathering, cross-laminated; sandstone is calcareous, very fine grained, dark grey, light brown weathering, cross-laminated and occurs near top of unit; unit is medium bedded, resistant and has a gradational lower contact.	3.6	3094.0
11-102	Claystone with minor siltstone; claystone is calcareous, dark grey, dark grey to brown weathering; siltstone is calcareous, dark grey, grey to yellow brown weathering and occurs near base of unit; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	1.1	3090.4
11-103	Siltstone with minor sandstone; siltstone is calcareous, dark grey to brown, light brown to brown weathering, cross-laminated; sandstone is calcareous, very fine grained, silty, dark grey to brown, grey to yellow brown weathering, cross-laminated and occurs near base; unit is medium bedded, moderately resistant and has a gradational	2.8	3089.3

Unit No.	Description	Thickness (Feet)	Feet Above Base
	lower contact.		
11-104	Claystone and siltstone; claystone is calcareous, silty in part, dark grey, yellow brown weathering; siltstone is calcareous, dark grey, grey to brown weathering; unit is thin bedded and has a sharp conformable lower contact.	2.6	3086.5
11-105	Claystone, minor sandstone and coal; claystone is calcareous, dark grey, dark grey to yellow brown weathering; sandstone is calcareous, dark grey, light grey weathering, cross-laminated and occurs at top of unit; coal occurs in a 24 centimeter thick seam below sandstone; unit is laminated to thin bedded, moderately recessive and has a gradational lower contact.	3.7	3083.9
11-106	Siltstone, calcareous, red brown to light brown weathering; unit is thin to medium bedded, moderately resistant and has a sharp conformable lower contact.	3.5	3080.2
11-107	Claystone; carbonaceous, dark grey to black, black weathering; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	3.8	3076.7
11-108	Siltstone; calcareous, dark grey, light brown weathering; unit is thin to medium bedded, resistant and has a gradational lower contact.	3.4	3072.9
11-109	Claystone; calcareous, silty, dark grey, dark grey to brown weathering; unit is laminated, moderately recessive and has a gradational lower contact.	2.3	3069.5
11-110	Siltstone with minor sandstone and claystone; siltstone is calcareous, dark grey, red brown to light brown weathering; sandstone is calcareous, very fine grained, dark grey, red brown to light brown weathering, cross-laminated and occurs near middle of unit; claystone is calcareous, dark grey, light brown weathering and occurs as interbeds; unit is laminated to medium bedded, moderately resistant and has a gradational lower contact.	9.6	3067.2
11-111	Claystone and coal; claystone is carbonaceous, dark grey, dark grey weathering; coal occurs in a 16 centimeter thick seam at top of unit; unit is laminated, recessive and has a gradational lower contact.	2.6	3057.6
11-112	Siltstone; calcareous, sandy, dark grey, grey to red brown weathering, cross-laminated; unit is medium to thick bedded, resistant and has a gradational lower contact.	6.2	3055.0
11-113	Claystone; carbonaceous, dark grey, dark grey weathering; unit is laminated, recessive and has a sharp conformable lower contact.	1.3	3048.8

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-114	Siltstone and minor claystone; siltstone is calcareous, sandy near base, dark grey, brown to rusty brown weathering, cross-laminated; claystone is calcareous, silty, dark grey, dark brown weathering and occurs as interbeds; unit is medium to thick bedded and moderately resistant.	12.5	3047.5
	Covered	5.3	3035.0
11-115	Sandstone; calcareous, very fine grained, silty, dark grey, light brown to red brown weathering, cross-laminated; unit is thin bedded and moderately resistant.	4.0	3029.7
	Covered	1.8	3025.7
11-116	Sandstone with minor siltstone; sandstone is calcareous, very fine grained, silty, dark grey, grey to light brown weathering, cross-laminated; siltstone is calcareous, dark grey, light brown weathering and occurs at top and bottom of unit; unit is medium to thick bedded, moderately resistant and has a sharp conformable lower contact.	8.9	3023.9
11-117	Claystone; carbonaceous, calcareous, dark grey to black, dark grey weathering, minor coal occurs near middle and at base of unit; unit is laminated, recessive and has a sharp conformable lower contact.	4.0	3015.0
11-118	Siltstone and minor claystone; siltstone is calcareous, sandy near middle of unit, dark grey, light brown to grey weathering, cross-laminated; claystone is calcareous, carbonaceous, dark grey to black, dark grey weathering, unit is medium bedded, moderately resistant and has a gradational lower contact.	14.2	3011.0
11-119	Sandstone; calcareous, very fine grained, silty, dark grey, grey to dark brown weathering, cross-laminated; unit is medium bedded, moderately resistant and has a sharp conformable lower contact.	1.9	2996.8
11-120	Claystone; dark grey, grey weathering, carbonaceous; minor coal occurs in a seam 10 centimeters thick at base of unit; unit is laminated, recessive and has a sharp conformable lower contact.	4.2	2994.9
11-121	Sandstone; calcareous, medium grained, dark brown to grey, grey to red brown weathering, cross-bedded; unit is medium to thick bedded and resistant.	35.0	2990.7
	Covered	10.0	2955.7
11-122	Siltstone; calcareous, dark grey to brown, grey weathering; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	1.6	2945.7

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-123	Siltstone; calcareous, dark grey, yellow brown to red brown weathering; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	3.0	2944.1
11-124	Sandstone; calcareous, very fine grained, fine grained near middle of unit, dark grey, yellow brown to grey brown weathering, cross-laminated; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	15.8	2941.1
11-125	Sandstone and minor siltstone; sandstone is calcareous, very fine to fine grained, dark grey, light brown to grey weathering, cross-laminated; siltstone is calcareous, dark grey, light brown weathering and occurs near top of unit; unit is very thin to medium bedded, resistant and has a sharp conformable lower contact.	15.6	2925.3
11-126	Sandstone; calcareous, medium to very coarse grained, grey to dark grey, grey brown weathering, cross-bedded; unit is thin to medium bedded and resistant.	23.0	2909.7
	Covered	3.3	2886.7
11-127	Claystone; carbonaceous, dark grey, dark grey weathering; unit is laminated and recessive.	1.1	2883.4
11-128	Sandstone; calcareous, very fine grained, dark grey, rusty brown weathering, cross-laminated; unit is thin bedded, moderately resistant and has a gradational lower contact.	2.4	2882.3
11-129	Claystone and minor siltstone; claystone is calcareous, carbonaceous, dark grey, yellow brown to grey weathering; siltstone is calcareous, dark grey, grey weathering; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	1.9	2879.9
11-130	Siltstone and minor claystone; siltstone is calcareous, sandy near top of unit, dark grey, dark grey to yellow brown weathering, cross-laminated; claystone is calcareous, dark grey, yellow brown weathering and occurs near middle of unit; unit is laminated to medium bedded and moderately resistant.	7.0	2878.0
	Covered	2.6	2871.0
11-131	Sandstone; calcareous, very fine grained, dark grey, grey brown weathering, cross-laminated; unit is medium bedded and moderately resistant.	1.9	2868.4
	Covered	1.2	2866.5
11-132	Sandstone and siltstone; sandstone is calcareous, very fine to fine grained, dark grey, red brown	9.9	2865.3

Unit No.	Description	Thickness (Feet)	Feet Above Base
	to grey weathering; siltstone is calcareous, sandy, dark grey, grey to red brown weathering and occurs at top of unit; unit is medium to thick bedded and resistant.		
	Covered	5.2	2885.4
11-133	Siltstone and minor claystone; siltstone is calcareous, dark grey, red brown to yellow brown weathering, mudstone is dark grey, red brown weathering and occurs at top and base of unit; unit is very thin to medium bedded and moderately resistant.	9.0	2850.2
	Covered	5.2	2841.2
11-134	Sandstone and minor siltstone; sandstone is calcareous, very fine to fine grained, silty near top, dark grey, grey brown to red brown weathering; siltstone is calcareous, dark grey, grey brown weathering and occurs near top and at base of unit; unit is thin bedded, moderately resistant and has a gradational lower contact.	7.9	2836.0
11-135	Claystone with minor siltstone; claystone is calcareous, silty in part, dark grey, dark brown weathering; siltstone is calcareous, dark grey, dark grey weathering, cross-laminated and occurs near middle of unit; unit is thin bedded, moderately recessive and has a gradational lower contact.	4.7	2828.1
11-136	Siltstone interbedded with minor claystone; siltstone is calcareous, dark grey, yellow brown to red brown weathering; claystone is calcareous, silty, dark grey, yellow brown weathering; unit is medium to thick bedded, moderately resistant and has a sharp conformable lower contact.	5.0	2823.4
11-137	Claystone and minor siltstone; claystone is calcareous, dark grey, brown yellow weathering; siltstone is calcareous, dark grey, brown weathering; unit is very thin to thin bedded and moderately recessive.	5.2	2818.4
	Covered	2.5	2813.2
11-138	Siltstone and sandstone; siltstone is calcareous, sandy in part, dark grey, yellow brown to red brown weathering; sandstone is calcareous, very fine grained, dark grey, grey brown weathering and occurs near base of unit, cross-laminated, minor calcareous, dark grey, yellow brown weathering, silty claystone occurs as interbeds; unit is very thin to medium bedded and moderately resistant.	10.5	2810.7
	Covered	3.7	2800.2
11-139	Siltstone with minor sandstone and claystone; siltstone is calcareous, dark grey, brown yellow weathering, cross-laminated; sandstone is		

Unit No.	Description	Thickness (Feet)	Feet Above Base
	calcareous, very fine grained, dark grey, brown yellow weathering and occurs near base of unit; claystone is calcareous, silty, dark grey, brown yellow weathering and occurs as interbeds; unit is very thin to medium bedded, resistant and has a sharp conformable lower contact.		
11-140	Sandstone; calcareous, very fine to medium grained, dark grey to grey, grey brown weathering, cross-laminated; minor calcareous, dark grey, brown weathering siltstone occurs as interbeds near top of unit, unit is thin to medium bedded and resistant.	15.1	2774.0
	Covered	3.8	2758.9
11-141	Sandstone with minor siltstone and claystone; sandstone is very fine to fine grained, calcareous, dark grey, brown yellow weathering, cross-laminated; siltstone is calcareous, dark grey, yellow brown weathering and occurs near top of unit; claystone is dark grey, dark grey weathering and occurs near middle of unit; unit is thin bedded, moderately resistant and has a gradational lower contact.	4.9	2755.1
11-142	Siltstone; calcareous, sandy, dark grey, grey brown weathering, cross-laminated, grades to very fine grained sandstone at base; unit is medium bedded, resistant and has a gradational lower contact.	4.2	2750.2
11-143	Claystone and minor siltstone; claystone is calcareous, silty in part, dark grey, rusty brown to yellow weathering; siltstone is calcareous, dark grey, rusty brown weathering; unit is laminated to very thin bedded and recessive.	3.5	2746.0
	Covered	3.6	2742.5
11-144	Siltstone; calcareous, dark grey, yellow brown to grey weathering, grades to very fine grained sandstone at base of unit; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	3.9	2738.9
11-145	Sandstone; calcareous, fine to medium grained, dark grey, brown weathering, cross-bedded; unit is thin to medium bedded, resistant and has a gradational lower contact.	5.2	2735.0
11-146	Sandstone and minor siltstone; sandstone is calcareous, fine to medium grained, dark grey, light grey weathering, cross-bedded; siltstone is calcareous, dark grey, grey weathering and occurs at top of unit; unit is medium to thick bedded, resistant and has a sharp conformable lower contact.	15.0	2729.8
11-147	Siltstone; calcareous, dark grey, rusty brown to yellow weathering, cross-laminated, grades to very fine grained sandstone at base; unit is medium to thick	6.4	2714.8

Unit No.	Description	Thickness (Feet)	Feet Above Base
	bedded, resistant and has a sharp conformable lower contact.		
11-148	Claystone and minor siltstone; claystone is dark grey to brown yellow weathering; siltstone is calcareous, dark grey, yellow brown weathering and occurs near top of unit; unit is thin to medium bedded, moderately recessive and has a gradational lower contact.	3.4	2708.4
11-149	Siltstone and minor sandstone; siltstone is calcareous, dark grey, dark grey to brown weathering; sandstone is calcareous, dark grey, brown weathering and occurs near base of unit; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	6.0	2705.0
11-150	Coal and carbonaceous claystone; coal occurs in a 25 centimeter thick seam at base of unit; claystone is calcareous, dark grey, dark grey weathering; unit is laminated, recessive and has a sharp conformable lower contact.	2.2	2699.0
11-151	Siltstone and minor claystone; siltstone is calcareous, dark grey, rusty brown to yellow weathering; claystone is dark grey, grey to brown weathering and occurs near base and in middle of unit; unit is medium to thick bedded, resistant and has a sharp conformable lower contact.	9.4	2696.8
11-152	Claystone; carbonaceous, dark grey, dark grey weathering minor coaly partings; unit is laminated to very thin bedded and recessive.	2.0	2687.4
11-153	Siltstone; calcareous, dark grey, brown to rusty brown weathering, becomes noncalcareous at top; minor, silty, calcareous, dark grey, brown weathering claystone occurs in interbeds; unit is medium bedded, moderately resistant and has a sharp conformable lower contact.	17.3	2685.4
11-154	Sandstone and minor siltstone; sandstone is calcareous, dark grey, grey to brown weathering, cross-laminated, siltstone is calcareous, dark grey, grey weathering and occurs at base of unit; unit is medium to thick bedded and resistant.	7.1	2668.1
	Covered	3.7	2661.0
11-155	Siltstone and minor claystone; siltstone is dark grey, dark grey weathering and grades to silty claystone at top of unit; unit is very thin to thin bedded, moderately recessive and has a gradational lower contact.	1.3	2657.3
11-156	Sandstone and siltstone; sandstone is calcareous, very fine to fine grained, dark grey, rusty brown to yellow brown weathering; siltstone is calcareous, dark grey, yellow brown weathering and occurs in	7.4	2656.0

Unit No.	Description	Thickness (Feet)	Feet Above Base
	lower part of unit; unit is medium bedded, moderately resistant and has a gradational lower contact.		
11-157	Claystone and minor siltstone; claystone is calcareous, silty, dark grey, brown to yellow brown weathering; siltstone is calcareous, dark grey, yellow brown to grey weathering and occurs in middle of unit; unit is very thin to thin bedded, moderately recessive and has a gradational lower contact.	2.4	2648.6
11-158	Siltstone and minor claystone; siltstone is calcareous, dark grey, brown weathering, cross-laminated; claystone is silty, calcareous, dark grey, grey brown weathering, and occurs near base of unit; unit is medium to thick bedded, moderately resistant and has a gradational lower contact.	5.4	2646.2
11-159	Claystone; carbonaceous, dark grey, dark grey weathering; unit is very thin bedded, recessive and has a gradational lower contact.	2.6	2640.8
11-160	Siltstone; calcareous near top of unit, dark grey, grey brown weathering, cross-laminated; unit is medium to thick bedded, resistant and has a gradational lower contact.	3.0	2638.2
11-161	Claystone; carbonaceous, silty, dark grey, dark grey weathering; unit is very thin bedded, recessive and has a gradational lower contact.	0.9	2635.2
11-162	Sandstone and minor siltstone; sandstone is calcareous, very fine to fine grained, grey to dark grey, red brown to brown weathering, cross-bedded; siltstone is dark grey, grey weathering and occurs at top of unit; unit is medium to very thick bedded, resistant and has a gradational lower contact.	12.7	2634.3
11-163	Sandstone; calcareous, fine to medium grained, grading to coarse and very coarse grained at base, grey to dark grey, light grey weathering, cross-bedded; minor pebbly sandstone at base of unit; unit is thick to very thick bedded, resistant and has a sharp disconformable lower contact.	18.0	2621.6
11-164	Siltstone with minor claystone and coal; siltstone is calcareous, dark grey, brown to red brown weathering; claystone is calcareous, dark grey, dark grey weathering, contains coaly partings and occurs as interbeds near top of unit; pyrite evident in some siltstone beds; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	13.3	2603.6
11-165	Siltstone; calcareous, dark grey, red brown weathering, cross-laminated; thin parting of dark grey, brown yellow weathering claystone occurs near middle of unit; unit is thin to medium bedded, moderately resistant and has a gradational lower	4.1	2590.3

Unit No.	Description	Thickness (Feet)	Feet Above Base
	contact.		
11-166	Claystone and minor siltstone; claystone is calcareous, dark grey, brown yellow to red brown weathering; siltstone is calcareous, grey, yellow brown weathering and occurs in lower part of unit; unit is very thin to thin bedded, moderately recessive and has a sharp conformable lower contact.	4.8	2586.2
11-167	Claystone; calcareous, grey, dark grey weathering, very hard, silty near top, unit is thin to medium bedded and moderately resistant.	1.3	2581.4
11-168	Siltstone; calcareous, dark grey, grey to red brown weathering, cross-laminated; unit is medium to thick bedded, resistant and has a sharp conformable lower contact.	3.0	2580.1
11-169	Claystone; carbonaceous, calcareous, dark grey, dark grey weathering; unit is very thin bedded, recessive and has a gradational lower contact.	1.5	2577.1
11-170	Siltstone; calcareous, dark grey, grey to brown weathering; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	1.2	2575.6
11-171	Claystone; carbonaceous, dark grey, dark grey weathering; unit is laminated to thin bedded, recessive and has a gradational lower contact.	2.2	2574.4
11-172	Sandstone with minor siltstone and claystone; sandstone is calcareous, very fine grained, dark grey, brown yellow to red brown weathering; minor calcareous, dark grey, yellow brown weathering claystone and siltstone occur near base of unit; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	5.0	2572.2
11-173	Claystone; carbonaceous, calcareous, dark grey, grey weathering, plant remains evident; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	2.0	2567.2
11-174	Siltstone and minor claystone; siltstone is calcareous, dark grey, red brown to yellow brown weathering, cross-laminated; claystone is carbonaceous, dark grey, dark grey to black weathering and occurs as interbeds; unit is thin to medium bedded, moderately resistant and has a sharp, conformable lower contact.	14.1	2565.2
11-175	Claystone and minor siltstone; claystone is carbonaceous, dark grey, grey brown weathering; siltstone is dark grey, dark grey weathering and occurs at top of unit; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	2.7	2551.1
11-176	Siltstone and sandstone; siltstone is calcareous,	13.3	2548.4

Unit No.	Description	Thickness (Feet)	Feet Above Base
	sandy in part, grey to brown weathering, cross-laminated; sandstone is calcareous, very fine to fine grained, dark grey, grey brown weathering, cross-laminated; unit is medium to thick bedded, moderately resistant and has a gradational lower contact.		
11-177	Sandstone; calcareous, fine to medium grained, grey, light grey weathering, cross-laminated; unit is medium to thick bedded; resistant and has a sharp conformable lower contact.	11.2	2535.1
11-178	Siltstone; calcareous, sandy, dark grey, light brown weathering; unit is medium bedded, moderately resistant and has a sharp disconformable lower contact.	3.8	2523.9
11-179	Sandstone; carbonaceous, calcareous, medium grained, grey to dark grey, grey weathering; unit is thin to medium bedded, moderately resistant and has a sharp conformable lower contact.	1.4	2520.1
11-180	Claystone; carbonaceous, dark grey to grey, dark grey weathering; 5 centimeter coal seam at top of unit; unit is very thin to thin bedded, recessive and has a gradational lower contact.	1.8	2518.7
11-181	Siltstone; calcareous, dark grey, brown to brown weathering, cross-laminated; minor calcareous, dark grey, grey weathering claystone occurs as interbeds near top of unit; unit is medium to thick bedded, moderately resistant and has a gradational lower contact.	12.5	2516.9
11-182	Claystone; dark grey, grey to yellow brown weathering; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	1.9	2504.4
11-183	Siltstone and sandstone; siltstone is calcareous, dark grey, brown to red brown weathering, cross-laminated; sandstone is calcareous, very fine grained, dark grey, grey to brown weathering, cross-laminated; minor calcareous claystone occurs as interbeds throughout the unit; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	18.7	2502.5
11-184	Siltstone; slightly calcareous, dark grey, light grey weathering, cross-laminated; unit is laminated to very thin bedded moderately resistant and has a gradational lower contact.	1.2	2483.8
11-185	Sandstone; calcareous, fine to medium grained, grey to dark grey, grey brown weathering, cross-laminated; unit is medium to thick bedded, resistant and has a gradational lower contact.	5.8	2482.6
11-186	Sandstone; calcareous, medium to coarse grained, dark	13.5	2476.8

Unit No.	Description	Thickness (Feet)	Feet Above Base
	grey, grey to dark grey weathering, cross-bedded; unit is medium to thick bedded, resistant and has a sharp conformable lower contact.		
11-187	Sandstone; calcareous, fine to medium grained grading to a chert pebble conglomerate at base of unit, dark grey to grey, brown to light brown weathering, cross-bedded; unit is medium bedded, resistant and has a sharp disconformable lower contact.	6.6	2463.3
11-188	Claystone with minor siltstone; claystone is calcareous, dark grey, brown to yellow brown weathering; siltstone is calcareous, sandy, dark grey, red brown weathering and occurs in middle of unit, unit is very thin to thin bedded, moderately recessive and has a sharp conformable lower contact.	1.9	2456.7
11-189	Sandstone; calcareous, medium grained, grey to dark grey, brown weathering; unit is thin bedded, moderately resistant and has a sharp conformable lower contact.	1.0	2454.8
11-190	Claystone and minor siltstone; claystone is calcareous, dark grey, yellow brown weathering; siltstone is sandy, dark grey, red brown weathering; unit is laminated, moderately recessive and has a sharp conformable lower contact.	1.5	2453.8
11-191	Siltstone and sandstone; siltstone is calcareous, dark grey, brown to yellow brown weathering; sandstone is calcareous, dark grey, brown yellow weathering and occurs in lower part of unit; minor calcareous, dark grey, brown to black weathering interbeds of claystone occur near top and base of unit; unit is medium to thick bedded and moderately resistant.	11.7	2452.3
	Covered	1.0	2440.6
11-192	Sandstone; calcareous, silty, dark grey, red brown weathering, cross-laminated; unit is medium to thick bedded, resistant and has a gradational lower contact.	3.7	2439.6
11-193	Siltstone with minor sandstone and claystone; siltstone is calcareous, dark grey, brown to red brown weathering, cross-laminated; sandstone is calcareous, dark grey, red brown to brown weathering, cross-laminated; claystone is dark grey, dark grey weathering and occurs as interbeds throughout the unit; unit is medium to thick bedded, moderately resistant and has a gradational lower contact.	26.4	2435.9
11-194	Sandstone and siltstone; sandstone is calcareous, very fine grained, dark grey, brown to red brown weathering; siltstone is calcareous, dark grey, brown weathering and occurs in lower part of unit; unit is thin to medium bedded, resistant and has a sharp conformable lower contact.	6.7	2409.5

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-195	Claystone with minor siltstone; claystone is calcareous, dark grey, grey to yellow brown weathering; siltstone is calcareous, dark grey, yellow brown weathering and occurs near top and at base of unit; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	5.0	2402.8
11-196	Siltstone; calcareous, dark grey, yellow brown to red brown weathering, cross-laminated, grades to very fine grained sandstone near middle of unit; unit is medium to thick bedded, moderately resistant and has a gradational lower contact.	9.0	2397.8
11-197	Claystone; carbonaceous, dark grey, black weathering, unit is laminated and recessive.	1.1	2388.8
	Covered	3.3	2387.7
11-198	Siltstone with minor claystone; siltstone is calcareous, dark grey, red brown to brown weathering, cross-laminated; claystone is calcareous, dark grey, dark grey weathering and occurs as interbeds throughout the unit; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	11.9	2384.4
11-199	Sandstone and siltstone; sandstone is calcareous, very fine grained, dark grey, light brown to grey weathering, cross-laminated; siltstone is calcareous, dark grey, brown weathering and occurs in lower part of unit; unit is thin to medium bedded, resistant and has a gradational lower contact.	3.5	2372.5
11-200	Claystone; carbonaceous, calcareous, dark grey, dark grey to black weathering; unit is laminated to thin bedded, recessive and has a gradational lower contact.	1.5	2369.0
11-201	Siltstone and minor sandstone; siltstone is calcareous, grey to dark grey, red brown weathering, cross-laminated; sandstone is calcareous, very fine grained, dark grey, brown to red brown weathering, cross-laminated and occurs near top of unit, unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	11.5	2367.5
11-202	Claystone with minor siltstone and coal, claystone is carbonaceous, calcareous in part, dark grey, dark grey weathering, siltstone is calcareous, dark grey, brown yellow weathering and occurs near middle of unit; a 6 centimeter thick seam of coal occurs near base of unit; unit is laminated to very thin bedded moderately recessive and has a sharp conformable lower contact.	2.7	2356.0
11-203	Sandstone; calcareous, very fine to fine grained, dark grey to grey, light brown to grey weathering, cross-laminated, grades to siltstone at	19.8	2353.3

Unit No.	Description	Thickness (Feet)	Feet Above Base
	base of unit; unit is medium to thick bedded, resistant and has a sharp conformable lower contact.		
11-204	Claystone; carbonaceous, dark grey, dark grey to black weathering, grades to siltstone at base; unit is laminated, recessive and has a gradational lower contact.	2.0	2333.5
11-205	Siltstone; calcareous, dark grey, dark brown to brown weathering, cross-laminated; minor, dark grey, brown yellow weathering, silty claystone occurs as interbeds throughout unit; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	8.6	2331.5
11-206	Claystone; calcareous, silty in part, dark grey, dark grey to brown yellow weathering; unit is laminated to thin bedded, moderately recessive and has a gradational lower contact.	3.7	2322.9
11-207	Sandstone; calcareous, very fine to fine grained, dark grey, red brown to brown weathering, cross-laminated; unit is thin to medium bedded, resistant and has a gradational lower contact.	2.9	2319.2
11-208	Claystone; carbonaceous, calcareous and silty near top of unit, dark grey, dark grey to yellow brown weathering; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	4.3	2316.3
11-209	Siltstone; calcareous, dark grey, grey to yellow brown weathering, grades to silty claystone near top of unit; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	3.7	2312.0
11-210	Siltstone and minor claystone; siltstone is calcareous, sandy, dark grey, yellow brown weathering, cross-laminated; claystone is calcareous, dark grey, yellow brown weathering and occurs near base of unit; unit is very thin to medium bedded, moderately resistant and has a sharp conformable lower contact.	5.7	2308.3
11-211	Claystone; carbonaceous, calcareous, dark grey, dark grey to yellow brown weathering; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	1.8	2302.6
11-212	Sandstone; calcareous, very fine to medium grained, dark grey, grey brown weathering, cross-laminated; unit is medium to thick bedded, resistant and has a sharp disconformable lower contact.	22.3	2300.8
11-213	Claystone and coal; claystone is carbonaceous, dark grey, black weathering; coal occurs in a 25 centimeter thick seam near middle of unit; unit is	2.0	2278.5

Unit No.	Description	Thickness (Feet)	Feet Above Base
	laminated to very thin bedded, recessive and has a gradational lower contact.		
11-214	Siltstone; calcareous, sandy, dark grey, dark grey to brown yellow weathering; unit is very thin to thin bedded, moderately recessive and has a gradational lower contact.	3.3	2276.5
11-215	Sandstone; calcareous, very fine to fine grained grading to medium grained at base, dark grey to grey, grey brown weathering, cross-laminated; unit is medium to very thick bedded, resistant and has a sharp conformable lower contact.	17.7	2273.2
11-216	Siltstone; calcareous, dark grey, grey brown weathering, cross-laminated; minor calcareous, dark grey, grey brown weathering claystone occurs as interbeds; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	15.4	2255.5
11-217	Claystone and siltstone; claystone is dark grey, dark grey weathering, carbonaceous; siltstone is calcareous, dark grey, grey to brown weathering and occurs at top of unit; unit is thin bedded, moderately recessive and has a sharp conformable lower contact.	1.4	2240.1
11-218	Sandstone; calcareous, very fine grained, grey brown weathering, cross-laminated; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	3.7	2238.7
11-219	Claystone; carbonaceous, dark grey, dark grey weathering; minor coal near middle of unit in a seam 9 centimeters thick; unit is laminated to thin bedded, recessive and has a gradational lower contact.	2.5	2235.0
11-220	Siltstone and sandstone; siltstone is calcareous, dark grey, brown to red brown weathering; sandstone is calcareous, very fine grained, dark grey, brown weathering; minor claystone occurs as interbeds throughout unit; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	17.5	2232.5
11-221	Claystone; carbonaceous, calcareous near top of unit, dark grey, weathers dark grey, plant remains evident; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	1.1	2215.0
11-222	Siltstone; calcareous, dark grey, grey brown to red brown weathering; minor dark grey, dark grey weathering, silty claystone occurs at top of unit; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	9.3	2213.9

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-223	Claystone, carbonaceous, dark grey, dark grey weathering; coal occurs in 2 seams, each 6 centimeters thick, near middle of unit; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	2.3	2204.6
11-224	Sandstone and siltstone; sandstone is calcareous, dark grey, brown to grey brown weathering, cross-laminated; siltstone is calcareous, dark grey, grey brown weathering, cross-laminated and occurs near base of unit; minor, calcareous, carbonaceous, dark grey, dark grey weathering claystone occurs near the top and in the middle of the unit; unit is medium to very thick bedded, resistant and has a gradational lower contact.	22.4	2202.3
11-225	Claystone; calcareous, carbonaceous, silty in part, dark grey, grey brown to yellow brown weathering; unit is very thin to thin bedded, moderately recessive and has a gradational lower contact.	2.3	2179.9
11-226	Siltstone with minor sandstone and claystone; siltstone is calcareous, dark grey, brown to red brown weathering, cross-laminated; sandstone is calcareous, very fine to fine grained, grey brown weathering and occurs near top of unit; claystone is dark grey, weathers grey to brown and occurs as interbeds throughout the unit; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	21.2	2177.6
11-227	Claystone and minor coal; claystone is carbonaceous, dark grey, black weathering; coal occurs in 2 thin seams near the top of the unit; unit is laminated, recessive and has a gradational lower contact.	7.0	2156.4
11-228	Siltstone and sandstone; siltstone is calcareous, dark grey, light brown to red brown weathering, cross-laminated; sandstone is very fine to fine grained, dark grey, light brown weathering, cross-laminated and occurs near base of unit; unit is thin to medium bedded, moderately resistant and has a sharp conformable lower contact.	22.4	2149.4
11-229	Siltstone and minor claystone, siltstone is calcareous, dark grey, brown to yellow brown weathering, cross-laminated; claystone is silty in part, dark grey, black to red brown weathering and occurs as interbeds throughout the unit; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	8.6	2127.0
11-230	Sandstone with minor siltstone; sandstone is calcareous, very fine grained, dark grey, brown to grey brown weathering, cross-laminated; siltstone is calcareous, dark grey, brown weathering, cross-laminated and occurs at top of unit; unit is thin	5.7	2118.7

Unit No.	Description	Thickness (Feet)	Feet Above Base
	to thick bedded, resistant and has a gradational lower contact.		
11-231	Siltstone and minor claystone; siltstone is calcareous, sandy, dark grey, brown to light brown weathering, cross-laminated and grades to very fine grained sandstone at base of unit; claystone is calcareous; silty and carbonaceous in part, dark grey, dark grey to yellow brown weathering and occurs as interbeds throughout unit; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	5.6	2112.7
11-232	Claystone; carbonaceous, slightly calcareous, dark grey,, dark grey weathering; coaly partings near top of unit; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	3.1	2107.1
11-233	Siltstone; calcareous, dark grey, brown to red brown weathering, cross-laminated; unit is laminated to thin bedded, moderately recessive and has a gradational lower contact.	2.8	2104.0
11-234	Claystone and coal; claystone is carbonaceous, dark grey, dark grey weathering; coal occurs in a seam 25 centimeters thick near middle of unit; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	5.9	2101.2
11-235	Siltstone; slightly calcareous, dark grey, light grey to brown weathering; unit is thin bedded, moderately resistant and has a gradational lower contact.	3.7	2095.3
11-236	Claystone; silty, dark grey, dark grey to red brown weathering; unit is laminated, recessive and has a gradational lower contact.	2.4	2091.6
11-237	Siltstone; calcareous, sandy in part, dark grey, brown to red brown weathering, grades to very fine grained sandstone near top of unit; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	4.7	2089.2
11-238	Sandstone; calcareous, fine to medium grained, dark grey, light brown to grey brown weathering, cross-laminated; unit is medium to thick bedded, resistant and has a sharp conformable lower contact.	8.5	2084.5
11-239	Claystone and minor siltstone; claystone is calcareous, dark grey, dark grey to brown weathering; siltstone is calcareous, dark grey, yellow brown weathering and occurs near top of unit; unit is very thin to thin bedded, moderately recessive and has a gradational lower contact.	3.7	2076.0
11-240	Siltstone; calcareous, dark grey, red brown to yellow brown weathering, cross-laminated, becomes sandy near middle of unit; unit is very thin to medium	14.0	2072.3

Unit No.	Description	Thickness (Feet)	Feet Above Base
	bedded, moderately resistant and has a gradational lower contact.		
11-241	Claystone and coal; claystone is carbonaceous, dark grey, dark grey to black weathering; coal occurs in a 30 centimeter thick seam near middle of unit; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	2.7	2058.3
11-242	Siltstone; calcareous, dark grey, brown to grey brown weathering, cross-laminated, grades to very fine grained sandstone near top; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	5.0	2055.6
11-243	Claystone; calcareous, silty, dark grey, dark grey to red brown weathering; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	2.4	2050.6
11-244	Silstone; calcareous, dark grey, dark grey to red brown weathering; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	6.0	2048.2
11-245	Claystone; dark grey, dark grey to black weathering; unit is laminated, recessive and has a gradational lower contact.	1.4	2042.2
11-246	Sandstone; calcareous, very fine grained, dark grey, red brown weathering; minor calcareous, dark grey, dark grey to brown yellow weathering siltstone and silty claystone occurs as interbeds dispersed throughout unit; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	7.0	2040.8
11-247	Claystone; calcareous, silty in part, dark grey, dark grey to grey weathering; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	2.5	2033.8
11-248	Sandstone; calcareous, dark grey, brown to grey weathering, cross-laminated; contains minor silty, dark grey, grey weathering claystone interbeds; unit is medium to thick bedded, moderately resistant and has a gradational lower contact.	5.2	2031.3
11-249	Coal and minor claystone; claystone is carbonaceous, dark grey, dark grey weathering and occurs at base of seam; unit is recessive and has a sharp conformable lower contact.	0.6	2026.1
11-250	Siltstone; slightly calcareous, dark grey, red brown weathering; unit is medium to thick bedded, moderately resistant and has a gradational lower contact.	6.5	2025.5
11-251	Claystone; carbonaceous, dark grey, dark grey to	1.3	2019.0

Unit No.	Description	Thickness (Feet)	Feet Above Base
	black weathering; unit is laminated to very thin bedded, recessive and has a gradational lower contact.		
11-252	Siltstone and sandstone; siltstone is calcareous, dark grey, yellow brown to rusty brown weathering, cross-laminated; sandstone is very fine to fine grained, dark grey, yellow brown weathering and occurs in middle of unit; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	14.3	2017.7
11-253	Claystone; calcareous, dark grey, dark brown to yellow brown weathering; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	2.9	2003.4
11-254	Claystone; calcareous, silty, dark grey, grey to yellow brown weathering; unit is thin to medium bedded, moderately recessive and has a gradational lower contact.	2.1	2000.5
11-255	Claystone; carbonaceous, dark grey, grey to black weathering; minor coaly partings near base of unit; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	7.1	1998.4
11-256	Siltstone; calcareous, dark grey, brown to red brown weathering, becomes noncalcareous at top of unit; unit is laminated to medium bedded, moderately resistant and has a sharp conformable lower contact.	9.7	1991.3
11-257	Claystone and coal; claystone is carbonaceous, calcareous, dark grey, dark grey to black weathering; coal occurs in a seam 25 centimeters thick near middle of unit, unit is very thin to thin bedded, recessive and has a gradational lower contact.	2.8	1981.6
11-258	Siltstone; calcareous, dark grey, red brown weathering; unit is thin to thick bedded, moderately resistant and has a sharp conformable lower contact.	4.2	1978.8
11-259	Claystone and minor coal; claystone is carbonaceous, dark grey, dark grey to grey weathering; coal occurs in a seam 6 centimeters thick at top of unit; unit is laminated to thin bedded, recessive and has a gradational lower contact.	2.4	1974.6
11-260	Siltstone; slightly calcareous, dark grey, grey to dark brown weathering; unit is medium bedded, moderately resistant and has a sharp conformable lower contact.	1.2	1972.2
11-261	Coal	1.1	1971.0
11-262	Claystone; calcareous, silty, dark grey, grey brown weathering; unit is medium bedded, moderately recessive and has a gradational lower contact.	2.1	1969.9

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-263	Claystone and minor coal; claystone is carbonaceous, dark grey, dark grey weathering; coal occurs in 2 thin seams, each about 15 centimeters thick at top and in middle of unit; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	2.8	1967.8
11-264	Siltstone; calcareous, light grey, grey to light brown weathering, grades to silty claystone at top of unit; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	16.5	1965.0
11-265	Siltstone; calcareous, dark grey, dark brown to brown weathering; grades to silty claystone at base of unit; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	2.6	1948.5
11-266	Claystone; carbonaceous, calcareous, dark grey, dark grey to black weathering; minor coal partings near base of unit; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	1.5	1945.9
11-267	Siltstone; calcareous, dark grey, brown to red brown weathering; minor silty, calcareous, dark grey, dark grey weathering, claystone interbeds are dispersed throughout unit; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	6.6	1944.4
11-268	Coal; minor carbonaceous claystone parting near top and at base of seam.	2.1	1937.8
11-269	Siltstone; calcareous, dark grey, grey brown to red brown weathering; unit is very thin to thin bedded, moderately recessive and has a gradational lower contact.	2.2	1935.7
11-270	Claystone; carbonaceous, dark grey, dark grey weathering; unit is very thin to thin bedded, recessive and has a gradational lower contact.	1.8	1933.5
11-271	Siltstone; calcareous, dark grey, brown to red brown weathering; unit is thin medium bedded, moderately resistant and has a gradational lower contact.	2.4	1931.7
11-272	Claystone and siltstone; claystone is silty, dark grey, dark grey to grey weathering, calcareous; siltstone is calcareous, dark grey, grey weathering; unit is laminated to very thin bedded, moderately resistant and has a gradational lower contact.	5.9	1929.3
11-273	Siltstone; calcareous, dark grey, brown to grey brown weathering, grades to silty claystone at base; unit is thin to medium bedded and moderately resistant.	6.1	1923.4
	Covered	3.2	1917.3

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-274	Siltstone; calcareous, dark grey, brown to red brown weathering; unit is very thin to medium bedded, moderately resistant and has a sharp conformable lower contact.	5.5	1914.1
	End of Segment 2		
	Mount Allan - Segment 3 - measured on the northeast face of Mount Allan in Section 28, Township 23, Range 9, West of the 5th Meridian.		
11-275	Sandstone; calcareous, medium to coarse grained grading to very coarse grained at base of unit, dark grey to grey, grey brown to red brown weathering, cross-laminated; unit is medium to thick bedded, resistant and has a gradational lower contact.	5.3	1908.6
11-276	Sandstone, calcareous, fine grained, dark grey, red brown to brown weathering; unit is medium bedded, resistant and has a sharp conformable lower contact.	1.4	1903.3
11-277	Siltstone; calcareous, dark grey, yellow brown to red brown weathering; minor silty, calcareous, dark grey, dark grey to yellow brown weathering claystone occurs near top of unit; unit is thin bedded, moderately resistant and has a gradational lower contact.	6.1	1901.9
11-278	Coal; minor carbonaceous claystone near top of seam.	1.0	1895.8
11-279	Siltstone; calcareous, carbonaceous, dark grey, brown to red brown weathering; unit is thin bedded, moderately resistant and has a gradational lower contact.	2.7	1894.8
11-280	Siltstone and claystone; siltstone is calcareous, dark grey, red brown to yellow brown weathering; claystone is calcareous, dark grey, black to yellow brown weathering and occurs near top and at base of unit; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	4.5	1892.1
11-281	Siltstone; calcareous, dark grey, yellow brown weathering; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	1.5	1887.6
11-282	Claystone; carbonaceous, dark grey, dark grey to grey weathering; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	0.6	1886.1
11-283	Siltstone; calcareous, dark grey, red brown to brown weathering, grades to sandy siltstone and very fine grained sandstone at base of unit; unit is medium to thick bedded, resistant and has a	5.0	1885.5

Unit No.	Description	Thickness (Feet)	Feet Above Base
	gradational lower contact.		
11-284	Siltstone; calcareous, dark grey, red brown to dark brown weathering; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	2.5	1880.5
11-285	Claystone; calcareous, dark grey, dark grey weathering; unit is laminated, recessive and has a gradational lower contact.	3.1	1878.0
11-286	Siltstone; calcareous, dark grey, brown to red brown weathering, cross-laminated; grades to very fine grained sandstone near base of unit; unit is medium bedded, resistant and has a gradational lower contact.	10.6	1874.9
11-287	Claystone; silty and calcareous at top of unit, carbonaceous near base, dark grey, dark grey to yellow brown weathering; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	5.5	1864.3
11-288	Siltstone with minor sandstone and claystone; siltstone is calcareous, dark grey, red brown to brown weathering, cross-laminated; sandstone is very fine grained, calcareous, dark grey, red brown weathering, cross-laminated and occurs near top of unit; claystone is carbonaceous, dark grey, dark grey to black weathering and occurs at base and in middle of unit; unit is medium to thick bedded, moderately resistant and has a gradational lower contact.	9.7	1858.8
11-289	Claystone; silty in part, carbonaceous, dark grey, dark grey weathering; minor coaly partings at bottom and in middle of unit; unit is very thin bedded, recessive and has a gradational lower contact.	1.7	1849.1
11-290	Siltstone; calcareous, sandy near top of unit, dark grey, grey brown weathering, cross-laminated; grades to very fine grained sandstone at top of unit; unit is medium bedded, moderately resistant and has a gradational lower contact.	6.1	1847.4
11-291	Coal with carbonaceous claystone parting at base of seam.	1.4	1841.3
11-292	Claystone; carbonaceous, dark grey, dark grey to black weathering; minor siltstone partings within unit; unit is laminated to medium bedded, moderately recessive and has a gradational lower contact.	2.8	1839.9
11-293	Siltstone; calcareous, dark grey, grey to dark brown weathering, cross-laminated; grades to very fine grained sandstone at base; unit is medium to thick bedded, resistant and has a gradational lower contact.	12.5	1837.1

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-294	Claystone; calcareous, carbonaceous in part, dark grey, grey weathering; minor coaly partings near base of unit; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	2.1	1824.6
11-295	Siltstone; dark grey, grey weathering; unit is medium bedded, moderately resistant and has a gradational lower contact.	1.4	1822.5
11-296	Sandstone; calcareous, medium grained grading to fine grained at top of unit, dark grey, light grey to brown weathering; unit is cross-laminated, medium to thick bedded, resistant and has a gradational lower contact.	19.9	1821.1
11-297	Claystone and minor siltstone; claystone is calcareous, silty in part, dark grey, yellow brown weathering; siltstone is calcareous, dark grey, grey weathering and occurs near top and in middle of unit; unit is laminated to very thin bedded, moderately recessive and has a sharp conformable lower contact.	11.5	1801.2
11-298	Sandstone; calcareous, silty in part, very fine grained, dark grey, brown to red brown weathering, cross-laminated; unit is medium bedded, resistant and has a sharp conformable lower contact.	1.3	1789.7
11-299	Claystone; carbonaceous, dark grey, grey to black weathering; minor coaly partings near top of unit; unit is thinly laminated to laminated, recessive and has a gradational lower contact.	1.1	1788.4
11-300	Claystone; silty, dark grey, black weathering; unit is laminated to very thin bedded, moderately recessive and has a sharp conformable lower contact.	0.8	1787.3
11-301	Siltstone; calcareous, sandy near top of unit, dark grey, light brown weathering, cross-laminated; minor silty, calcareous, dark grey, grey to dark brown weathering claystone occurs as interbeds throughout the unit; unit is laminated to medium bedded, moderately resistant and has a gradational lower contact.	4.5	1786.5
11-302	Claystone; silty, dark grey, grey brown to rusty brown weathering, cross-laminated; unit is laminated to thin bedded, moderately resistant and has a gradational lower contact.	2.6	1782.0
11-303	Sandstone; calcareous, very fine grained, silty, dark grey, brown to dark brown weathering, cross-laminated; unit is medium to thick bedded, resistant and has a gradational lower contact.	6.6	1779.4
11-304	Sandstone; calcareous, fine to medium grained grading to coarse grained at base of unit, dark grey,	15.1	1772.8

Unit No.	Description	Thickness (Feet)	Feet Above Base
	grey to red brown weathering, cross-bedded; unit is medium to thick bedded, resistant and has a gradational lower contact.	15.1	1772.8
11-305	Sandstone; calcareous, medium to coarse grained, dark grey to grey, light grey brown weathering; unit is medium to thick bedded, resistant and has a sharp conformable lower contact.	12.8	1757.7
11-306	Siltstone; calcareous, dark grey, red brown weathering; unit is medium bedded, moderately resistant and has a gradational lower contact.	4.5	1744.9
11-307	Claystone; silty and calcareous near top, carbonaceous near base of unit, dark grey, dark grey to yellow brown weathering; unit is thinly laminated to laminated, recessive and has a gradational lower contact.	1.2	1740.4
11-308	Sandstone and siltstone; sandstone is calcareous, silty, very fine grained, dark grey, red brown weathering, cross-laminated; siltstone is sandy, dark grey, brown to red brown weathering, calcareous, cross-laminated and occurs near top of unit; unit is medium bedded, resistant and has a sharp conformable lower contact.	2.6	1739.2
11-309	Claystone and coal; claystone is calcareous, carbonaceous, dark grey, dark grey to black weathering; coal occurs in a 15 centimeter thick seam at base of unit; unit is very thin bedded, recessive and has a gradational lower contact.	4.3	1736.6
11-310	Siltstone; calcareous, dark grey, brown to red brown weathering, cross-laminated, grades to very fine grained sandstone near top; minor claystone interbeds occur throughout unit; unit is medium to thick bedded, moderately resistant and has a gradational lower contact.	4.6	1732.3
11-311	Claystone and coal; claystone is carbonaceous, calcareous, silty in part, dark grey, dark grey weathering; coal occurs in a 50 centimeter thick seam at top of unit; unit is laminated to thin bedded, recessive and has a gradational lower contact.	2.5	1727.7
11-312	Siltstone; calcareous, dark grey, dark brown weathering, cross-laminated; unit is medium bedded, moderately resistant and has a sharp conformable lower contact.	1.0	1725.2
11-313	Claystone; carbonaceous, dark grey, dark grey to black weathering, plant remains evident on bedding planes; unit is laminated to thin bedded, moderately recessive and has a gradational lower contact.	1.4	1724.2
11-314	Siltstone; calcareous, dark grey, brown to red brown weathering; unit is very thin to thin bedded,	3.2	1722.8

Unit No.	Description	Thickness (Feet)	Feet Above Base
	moderately resistant and has a gradational lower contact.		
11-315	Claystone; carbonaceous, dark grey, dark grey to black weathering; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	3.2	1719.6
11-316	Sandstone; calcareous, very fine grained, dark grey, dark brown to red brown weathering, cross-laminated; unit is thin to medium bedded, resistant and has a gradational lower contact.	5.5	1716.4
11-317	Siltstone and claystone; siltstone is calcareous, sandy, dark grey, grey weathering, cross-laminated; claystone is calcareous in part, carbonaceous, dark grey, dark grey to black weathering and occurs at top of unit; plant remains evident on some bedding planes; unit is laminated to medium bedded, moderately resistant and has a gradational lower contact.	8.7	1710.9
11-318	Claystone; carbonaceous, dark grey, dark grey to black weathering; unit is laminated, recessive and has a gradational lower contact.	0.9	1702.2
11-319	Siltstone; calcareous, dark grey, dark brown to brown weathering, cross-laminated; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	3.5	1701.3
11-320	Claystone and minor coal; claystone is carbonaceous, dark grey, grey to black weathering; coal occurs in a 20 centimeter thick seam near middle of unit; unit is very thin bedded, recessive and has a gradational lower contact.	4.1	1697.8
11-321	Claystone; silty in part, dark grey, grey to dark brown weathering, carbonaceous near base; unit is laminated to medium bedded, moderately recessive and has a gradational lower contact.	5.5	1693.7
11-322	Siltstone; calcareous, sandy, dark grey, dark brown weathering, cross-laminated; grades to very fine grained sandstone at top of unit; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	4.9	1688.2
11-323	Claystone; calcareous, dark grey, dark grey to yellow brown weathering; unit is laminated to very thin bedded, moderately recessive and has a sharp conformable lower contact.	2.5	1683.3
11-324	Siltstone; calcareous, dark grey, dark brown to red brown weathering, cross-laminated; grades to very fine grained sandstone at base; minor dark grey, yellow brown weathering claystone occurs as interbeds throughout unit; unit is thin to medium	9.2	1680.8

Unit No.	Description	Thickness (Feet)	Feet Above Base
	bedded, moderately resistant and has a gradational lower contact.		
	Covered	6.1	1671.6
11-325	Sandstone; very fine to fine grained, calcareous, dark grey, grey brown to red brown weathering; cross-laminated; minor siltstone and silty claystone occurs at top of unit; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	7.4	1665.5
11-326	Claystone and coal; claystone is carbonaceous, dark grey, grey to dark grey weathering; coal occurs in a 20 centimeter thick seam near middle of unit; unit is laminated to thin bedded, recessive and has a sharp conformable lower contact.	5.5	1658.1
11-327	Sandstone and minor claystone; sandstone is calcareous, very fine grained, dark grey, grey to red brown weathering, cross-laminated; claystone occurs as interbeds throughout unit; unit is thin to medium bedded, moderately resistant and has a sharp conformable lower contact.	6.3	1652.6
11-328	Claystone; carbonaceous, dark grey, grey to black weathering; unit is laminated to thin bedded, recessive and has a gradational lower contact.	3.1	1646.3
11-329	Siltstone with minor sandstone and claystone; siltstone is calcareous, dark grey, brown to red brown weathering, cross-laminated and grades to very fine and fine grained sandstone at base; claystone is calcareous, silty, dark grey, red brown to yellow brown weathering and occurs as interbeds throughout unit; unit is medium bedded and moderately resistant.	11.9	1643.2
	Covered	8.1	1631.3
11-330	Claystone and minor coal; claystone is carbonaceous, dark grey, grey to black weathering; coal occurs in a 20 centimeter thick seam near middle of unit; unit is very thin bedded, recessive and has a gradational lower contact.	2.0	1623.2
11-331	Siltstone; calcareous, dark grey, brown to red brown weathering; unit is very thin to thin bedded, moderately recessive and has a gradational lower contact.	2.2	1621.2
11-332	Claystone; calcareous, silty, dark grey, dark grey weathering; unit is laminated, recessive and has a sharp conformable lower contact.	1.4	1619.0
11-333	Siltstone; calcareous, dark grey, brown to light brown weathering, cross-laminated; unit is thin to medium bedded, moderately resistant and has a	6.6	1617.6

Unit No.	Description	Thickness (Feet)	Feet Above Base
	sharp conformable lower contact.		
11-334	Siltstone and minor claystone; siltstone is calcareous, dark grey, grey to brown yellow weathering; claystone is dark grey, dark grey weathering and occurs near top of unit; unit is very thin to thin bedded, moderately recessive and has a sharp conformable lower contact.	4.3	1611.0
11-335	Sandstone; calcareous, very fine grained, dark grey, brown to light brown weathering; unit is thin to medium bedded, resistant and has a gradational lower contact.	2.0	1606.7
11-336	Claystone; carbonaceous, dark grey, grey to brown yellow weathering; unit is laminated, moderately recessive and has sharp conformable lower contact.	3.2	1604.7
11-337	Sandstone with minor siltstone and claystone; sandstone is calcareous, very fine grained, dark grey, brown to red brown weathering, cross-laminated; grades to siltstone near top of unit; claystone is dark grey, yellow brown weathering and occurs as interbeds throughout unit; unit is laminated to thin bedded, moderately resistant and has a gradational lower contact.	5.9	1601.5
11-338	Claystone; calcareous, dark grey, dark grey to brown weathering; unit is laminated to very thin bedded and recessive.	2.3	1595.6
	Covered	1.8	1593.3
11-339	Sandstone; calcareous, very fine grained, dark grey, brown to dark brown weathering, cross-laminated; unit is thin to medium bedded, resistant and has a sharp conformable lower contact.	6.8	1591.5
11-340	Siltstone; calcareous, dark grey, dark grey to grey weathering; minor claystone interbeds occur throughout unit; unit is thin bedded, moderately resistant and has a sharp conformable lower contact.	2.5	1584.7
11-341	Sandstone and minor coal; sandstone is calcareous, silty in part, very fine to fine grained, dark grey, brown to light brown weathering, cross-laminated; coal occurs in a 12 centimeter thick seam at top of unit; unit is thin to medium bedded, moderately resistant and has a sharp conformable lower contact.	5.5	1582.2
11-342	Claystone with minor siltstone and coal; claystone is calcareous, carbonaceous near top, dark grey, grey to black weathering, siltstone calcareous, dark grey, dark brown to brown weathering and occurs near base of unit; minor coaly partings occur near top of unit; unit is laminated to very thin bedded, recessive and has a gradational	3.7	1576.7

Unit No.	Description	Thickness (Feet)	Feet Above Base
	lower contact.		
11-343	Siltstone; calcareous, dark grey, red brown to yellow brown weathering; grades to very fine grained sandstone at base of unit; unit is thin to medium bedded, resistant and has a gradational lower contact.	8.5	1573.0
11-344	Claystone and minor siltstone; calystone is carbonaceous, dark grey, grey to dark grey weathering; siltstone is calcareous, dark grey, grey weathering and occurs near top of unit; unit is laminated to thin bedded, recessive and has a gradational lower contact.	3.1	1564.5
11-345	Claystone and minor siltstone; claystone is calcareous, dark grey, brown to yellow brown weathering; siltstone is calcareous, dark grey, grey brown weathering and occurs near top of unit; unit is laminated to thinly bedded, moderately recessive and has a gradational lower contact.	10.6	1561.4
11-346	Siltstone; calcareous, sandy, dark grey, grey brown weathering, cross-laminated; unit is very thin to medium bedded and moderately resistant.	4.8	1550.8
	Covered	5.5	1546.0
11-347	Sandstone; calcareous, silty, very fine grained, dark grey, brown to grey brown weathering, cross-laminated; unit is thin to medium bedded and moderately resistant.	2.4	1540.5
	Covered	8.9	1538.1
11-348	Sandstone; calcareous, very fine grained, dark grey, grey weathering; unit is thin bedded, moderately resistant and has a gradational lower contact.	1.6	1529.2
11-349	Claystone and minor coal; claystone is carbonaceous, dark grey, dark grey to black weathering; coal occurs in a 15 centimeter thick seam near middle of unit; unit is very thin to thin bedded, recessive and has a gradational lower contact.	2.9	1527.6
11-350	Siltstone and minor sandstone; siltstone is calcareous, dark grey, rusty brown to brown weathering, cross-laminated; sandstone is calcareous, dark grey, grey to brown weathering, cross-laminated; minor silty, calcareous, dark grey, grey to black weathering claystone occurs at top of unit; unit is thin to medium bedded, moderately resistant and has a sharp conformable lower contact.	18.6	1524.7
11-351	Siltstone; calcareous, dark grey, grey to black weathering; unit is laminated, moderately recessive and has a gradational lower contact.	1.0	1506.1
11-352	Siltstone and minor claystone; siltstone is calcareous, dark grey, dark brown to brown weathering,	10.9	1505.1

Unit No.	Description	Thickness (Feet)	Feet Above Base
	cross-laminated; claystone is calcareous, dark grey, grey to yellow brown weathering and occurs as interbeds throughout unit; unit is laminated to thin bedded, moderately resistant and has a gradational lower contact.		
11-353	Claystone; dark grey, dark grey to dark brown weathering, unit is thinly laminated to laminated, recessive and has a gradational lower contact.	3.6	1494.2
11-354	Siltstone; calcareous, dark grey, dark brown to brown weathering; minor claystone occurs at top of unit; unit is medium bedded, moderately resistant and has a gradational lower contact.	5.8	1490.6
11-355	Claystone; calcareous, silty, dark grey, dark grey to black weathering; unit is laminated, moderately recessive and has a gradational lower contact.	1.1	1484.8
11-356	Sandstone; calcareous, very fine grained, dark grey, grey to light brown weathering; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	2.3	1483.7
11-357	Claystone and coal; claystone is carbonaceous, dark grey, dark grey to black weathering and silty; coal occurs in 2 seams each about 25 centimeters thick near middle and at base of unit; unit is laminated to thin bedded, recessive and has a gradational lower contact.	4.8	1481.4
11-358	Claystone and siltstone; claystone is calcareous, dark grey, dark grey to black weathering; siltstone is calcareous, dark grey, light brown weathering and occurs near middle and at top of unit; unit is laminated to thin bedded, moderately recessive and has a gradational lower contact.	12.5	1476.6
11-359	Sandstone; calcareous, dark grey, light brown weathering, cross-laminated; unit is thin bedded, moderately resistant and has a gradational lower contact.	3.1	1464.1
11-360	Claystone; silty, dark grey, dark grey weathering; unit is laminated, moderately recessive and has gradational lower contact.	2.3	1461.0
11-361	Siltstone, dark grey, grey to red brown weathering; unit is thin bedded, moderately resistant and has a gradational lower contact.	3.2	1458.7
11-362	Claystone; silty, grades to siltstone near base of unit, dark grey, grey brown to black weathering; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	3.4	1455.5
11-363	Siltstone; calcareous, dark grey, rusty brown to yellow weathering, cross-laminated; unit is medium bedded, resistant and has a sharp conformable lower contact.	6.1	1452.1

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-364	Sandstone; calcareous, very fine grained, dark grey, grey weathering, cross-laminated; unit is medium to thick bedded, resistant and has a sharp conformable lower contact.	7.7	1446.0
11-365	Sandstone; calcareous, fine grained, dark grey, light grey weathering; unit is thin to medium bedded, moderately resistant and has a sharp conformable lower contact.	2.0	1438.3
11-366	Claystone; calcareous, carbonaceous in part, dark grey, grey brown to black weathering; unit is laminated to very thin bedded recessive and has a sharp conformable lower contact.	8.4	1436.3
11-367	Sandstone; calcareous, very fine grained, dark grey, grey brown to red brown weathering; unit is very thin to thin bedded, moderately resistant and has a sharp conformable lower contact.	5.2	1427.9
11-368	Siltstone; slightly calcareous, dark grey, grey to dark grey weathering; grades to very fine grained sandstone at base; minor dark grey, black weathering claystone occurs as interbeds throughout unit; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	4.8	1422.7
11-369	Siltstone; dark grey, brown to grey brown weathering, cross-laminated, grades to very fine grained sandstone at base; unit is very thin to medium bedded, resistant and has a gradational lower contact.	3.1	1417.9
11-370	Claystone and minor coal; claystone is carbonaceous, dark grey, dark grey to black weathering; coal occurs in a 10 centimeter thick seam near middle of unit; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	4.2	1414.8
11-371	Sandstone; calcareous, very fine grained, dark grey, brown to red brown weathering, cross-laminated; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	3.4	1410.6
11-372	Claystone; calcareous, silty, dark grey, dark grey to yellow brown weathering; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	2.4	1407.2
11-373	Siltstone and claystone; siltstone is calcareous, dark grey, dark brown weathering; claystone is silty in part, carbonaceous, dark grey, grey to black weathering and occurs in lower part of unit, unit is very thin to thin bedded, moderately resistant and has a sharp conformable lower contact.	4.1	1404.8
11-374	Sandstone; calcareous, silty near top of unit, dark grey, red brown weathering, cross-laminated; unit is very thin to thin bedded, resistant and has a sharp conformable lower contact.	3.1	1400.7

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-375	Claystone; carbonaceous, calcareous in part, grades to siltstone at top of unit, dark grey, grey to black weathering; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	3.4	1397.6
11-376	Siltstone; calcareous, dark grey, brown to light brown weathering; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	2.6	1394.2
11-377	Claystone; carbonaceous, dark grey, dark grey to black weathering; unit is thinly laminated to laminated, recessive and has a gradational lower contact.	3.5	1391.6
11-378	Siltstone; calcareous, grades to very fine grained sandstone at base of unit, dark grey, red brown weathering, cross-laminated; unit is thin bedded, moderately resistant and has a gradational lower contact.	4.0	1388.1
11-379	Claystone; carbonaceous, silty and calcareous near top of unit, dark grey, brown to dark grey weathering; grades to siltstone at top of unit; unit is laminated to very thin bedded, moderately recessive and has a sharp conformable lower contact.	5.8	1384.1
11-380	Siltstone; calcareous, dark grey, brown to light brown weathering; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	1.0	1378.3
11-381	Claystone; silty, calcareous, dark grey, yellow brown to black weathering; unit is laminated to thin bedded, moderately recessive and has a gradational lower contact.	3.5	1377.3
11-382	Claystone; calcareous in part, dark grey, dark grey to yellow brown weathering; grades to siltstone at top of unit; unit is laminated, moderately recessive and has a gradational lower contact.	10.2	1373.8
11-383	Siltstone; calcareous, dark grey, grey brown to red brown weathering; minor, silty, calcareous, dark grey, dark grey to grey weathering claystone occurs as interbeds throughout unit; unit is thin to medium bedded, resistant and has a gradational lower contact.	47.8	1363.6
11-384	Siltstone; calcareous, dark grey, grey to yellow brown weathering, siltstone is finer grained than that of unit 11-383; unit is laminated to very thin bedded, moderately resistant and has a gradational lower contact.	17.9	1315.8
11-385	Claystone; dark grey, light grey to grey weathering; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	2.7	1297.9

Unit No.	Description	Thickness (Feet)	Feet Above Base
	Base of interbedded sandstone, siltstone and shale unit.		
11-386	Coal and minor claystone; coal is soft and oxidized; claystone partings are carbonaceous, dark grey, dark grey to black weathering and occur from 2 to 3 feet, 13 to 16 feet and 24 to 26 feet from top of unit; unit is laminated, very recessive and has a gradational lower contact.	30.0	1295.2
11-387	Claystone and minor siltstone; claystone is carbonaceous, dark grey, dark grey to black weathering; siltstone is dark grey, grey to red brown weathering and occurs at base of unit; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	3.5	1265.2
11-388	Sandstone; slightly calcareous, fine grained, dark grey, yellow brown weathering, cross-laminated; unit is thin bedded, resistant and has a gradational lower contact.	1.0	1261.7
11-389	Siltstone; slightly calcareous, dark grey, grey weathering, cross-laminated; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	4.0	1260.7
11-390	Coal and minor claystone; coal is fairly hard, bright and blocky; claystone is carbonaceous, dark grey, black weathering and occurs at top of seam; unit is very thin bedded, recessive and has a gradational lower contact.	1.6	1256.7
11-391	Claystone and minor siltstone; claystone is carbonaceous, dark grey, black weathering; siltstone is dark grey, grey weathering and occurs at top of unit; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	2.0	1255.1
11-392	Claystone and minor siltstone; claystone is silty, calcareous, dark grey, grey to brown weathering and grades to siltstone at top of unit; unit is laminated to thin bedded, moderately recessive and has a gradational lower contact.	4.6	1253.1
11-393	Claystone and minor coal; claystone is carbonaceous, silty, calcareous, dark grey, grey to dark grey weathering, grades to siltstone at top of unit; coal occurs in a 25 centimeter thick seam at base of unit; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	4.1	1248.5
11-394	Claystone; calcareous, dark grey, grey weathering; unit is laminated, moderately recessive and has a gradational lower contact.	1.6	1244.4
11-395	Siltstone; calcareous, dark grey, grey to light	7.1	1242.8

Unit No.	Description	Thickness (Feet)	Feet Above Base
	brown weathering; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.		
11-396	Claystone; silty, calcareous, dark grey, grey to dark grey weathering; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	2.6	1235.7
11-397	Siltstone; calcareous, dark grey, rusty brown to orange weathering, cross-laminated; minor silty, calcareous, dark grey, black weathering claystone occurs as interbeds throughout unit; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	3.7	1233.1
11-398	Claystone; silty, dark grey, grey to light brown weathering; unit is laminated, moderately recessive and has a gradational lower contact.	5.7	1229.4
11-399	Sandstone; calcareous, dark grey, brown to orange brown weathering, very fine grained, cross-laminated; unit is thin bedded, moderately resistant and has a gradational lower contact.	4.0	1223.7
11-400	Claystone; becomes silty near top, calcareous in part, dark grey, dark grey to rusty brown weathering; grades to siltstone at top of unit; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	12.9	1219.7
11-401	Coal	0.9	1206.8
11-402	Sandstone; slightly calcareous, very fine grained, grading to fine grained near base, dark grey, grey to dark brown weathering, cross-laminated; minor, silty, calcareous, dark grey, dark grey to black weathering claystone occurs as interbeds throughout unit; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	11.6	1205.9
11-403	Sandstone and minor siltstone; sandstone is slightly calcareous, fine grained, grey, brown grey weathering, cross-laminated; siltstone is sandy, dark grey, orange brown weathering and occurs near top of unit; unit is thin to thick bedded, resistant and has a gradational lower contact.	7.3	1194.3
11-404	Sandstone with minor siltstone and claystone; sandstone is calcareous, very fine grained, dark grey, grey to brown weathering, cross-laminated; siltstone is calcareous, dark grey, grey weathering and occurs near middle of unit; claystone is silty, calcareous, dark grey, dark grey to grey weathering and occurs as interbeds throughout unit; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	11.5	1187.8

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-405	Sandstone; calcareous, very fine to fine grained, dark grey to grey, grey to light grey weathering, cross-laminated; unit is medium to thick bedded and moderately resistant.	8.9	1175.5
	Covered	3.8	1166.6
11-406	Sandstone; calcareous, very fine grained, dark grey to grey, grey to dark brown weathering, cross-laminated; unit is thin bedded and moderately resistant.	5.4	1162.8
	Covered	3.6	1157.4
11-407	Siltstone; calcareous, dark grey, brown to yellow brown weathering; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	1.5	1153.8
11-408	Sandstone; calcareous, very fine grained, dark grey, grey weathering, cross-laminated; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	2.1	1152.3
11-409	Sandstone with claystone; sandstone is calcareous, very fine grained, dark grey, grey weathering; claystone is carbonaceous, calcareous, dark grey, grey weathering and occurs in middle of unit; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	5.3	1150.2
11-410	Sandstone; calcareous, fine grained, dark grey, brown to red brown weathering, cross-laminated; unit is medium to thick bedded, resistant and has a sharp conformable lower contact.	5.7	1144.9
11-411	Claystone; calcareous, silty, dark grey, dark brown to red brown weathering, cross-laminated; unit is laminated to thin bedded and has a gradational lower contact.	3.9	1139.2
11-412	Coal with minor carbonaceous claystone partings near top of seam.	0.6	1135.3
11-413	Claystone and minor siltstone; claystone is carbonaceous, dark grey to black, dark grey to black weathering; siltstone is calcareous, dark grey, dark brown to brown weathering and occurs at top and in middle of unit; unit is laminated to thin bedded, moderately recessive and has a gradational lower contact.	10.5	1134.7
11-414	Coal with minor interbeds of carbonaceous claystone; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	1.0	1124.2
11-415	Siltstone; calcareous, dark grey, brown to dark brown weathering, cross-laminated; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	4.3	1123.2

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-416	Claystone; calcareous in part, dark grey to black, grey to dark grey weathering; grades to siltstone near top of unit; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	5.2	1118.9
11-417	Siltstone; carbonaceous, dark grey, grey to grey brown weathering; unit is thin bedded, moderately resistant and has a gradational lower contact.	3.3	1113.7
11-418	Coal	2.8	1110.4
11-419	Siltstone; slightly calcareous, dark grey, grey weathering; grades to very fine grained sandstone at base; minor carbonaceous, dark grey, black weathering claystone occurs near top of unit; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	6.6	1107.6
11-420	Sandstone; calcareous, very fine grained, dark grey, brown to rusty brown weathering, silty near middle of unit; minor, calcareous, dark grey, black weathering interbeds of claystone occur throughout unit; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	13.1	1101.0
11-421	Siltstone; calcareous, dark grey, grey to dark brown weathering; minor, silty, dark grey, black weathering claystone occurs as interbeds throughout unit; unit is laminated, moderately recessive and has a gradational lower contact.	3.6	1087.9
11-422	Siltstone; dark grey, grey brown to orange brown weathering; slightly calcareous, cross-laminated; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	3.4	1084.3
11-423	Claystone and minor sandstone; claystone is dark grey, grey weathering; sandstone is calcareous, very fine grained, dark grey, grey weathering and occurs near top and in middle of unit; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	8.3	1080.9
11-424	Coal with minor carbonaceous claystone at top of seam.	4.5	1072.6
11-425	Claystone and sandstone; claystone is carbonaceous, dark grey, black weathering; sandstone is calcareous, grey, grey weathering and occurs in top part of unit; unit is laminated to thin bedded and moderately recessive.	5.0	1068.1
	Covered	5.5	1063.1
11-426	Sandstone and minor siltstone; sandstone is calcareous, very fine to fine grained, dark grey, grey brown to rusty brown weathering, cross-laminated; siltstone is calcareous, dark grey, dark grey	6.6	1057.6

Unit No.	Description	Thickness (Feet)	Feet Above Base
	weathering and occurs near top of unit; unit is laminated to thinly bedded, moderately resistant and has a gradational lower contact.		
11-427	Claystone; dark grey, dark grey weathering; unit is laminated to thin bedded, moderately recessive and has a gradational lower contact.	3.8	1051.0
11-428	Sandstone; silty, calcareous, very fine grained, dark grey, brown to red brown weathering, cross-laminated; minor, silty, calcareous, dark grey, grey brown to yellow brown weathering claystone occurs as interbeds at top and in middle of unit; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	9.3	1047.2
11-429	Claystone and siltstone; claystone is dark grey, dark grey weathering; siltstone is calcareous, dark grey, grey brown weathering and occurs near top of unit; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	3.5	1037.9
11-430	Coal and minor claystone; claystone is dark grey, black weathering and occurs at top and near base of seam.	4.1	1034.4
11-431	Coal and claystone; claystone is carbonaceous, dark grey, dark grey to black weathering and occurs near base and the top of unit.	9.3	1030.3
11-432	Siltstone; calcareous, dark grey, grey brown to red brown weathering; minor, silty, calcareous, dark grey, light grey to brown weathering claystone occurs as interbeds throughout unit; unit is laminated to thin bedded, moderately resistant and has a gradational lower contact.	3.1	1021.0
11-433	Claystone with minor siltstone and sandstone; claystone is carbonaceous in part, dark grey, dark grey weathering; siltstone is calcareous, dark grey, dark grey weathering and occurs near base of unit; sandstone is calcareous, dark grey, grey weathering and occurs near top of unit; unit is very thin bedded, moderately recessive and has a gradational lower contact.	14.2	1017.9
11-434	Claystone with minor siltstone and sandstone; claystone is dark grey, grey to dark brown weathering; siltstone is calcareous, dark grey, dark brown to grey weathering, cross-laminated; sandstone is calcareous, very fine grained, dark grey, brown weathering, cross-laminated and occurs near middle of unit; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	6.2	1003.7
11-435	Siltstone; calcareous, dark grey, grey weathering; unit is laminated to very thin bedded, moderately	16.0	997.5

Unit No.	Description	Thickness (Feet)	Feet Above Base
	recessive and has a gradational lower contact.		
11-436	Sandstone; calcareous, very fine grained, dark grey, grey to brown yellow weathering; grades to siltstone at top of unit; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	31.2	981.5
11-437	Sandstone; calcareous, very fine to fine grained, dark grey to brown, grey weathering, cross-laminated; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	7.5	950.3
11-438	Sandstone; calcareous, medium grained, dark brown to grey, grey weathering; unit is laminated to very thin bedded, resistant and has a gradational lower contact.	3.2	942.8
11-439	Sandstone; medium grained, dark grey, grey to brown weathering, cross-laminated; unit is medium to thick bedded, resistant and has a sharp locally disconformable lower contact.	25.0	939.6
11-440	Siltstone; calcareous, dark grey, dark grey to rusty brown weathering, cross-laminated; grades to very fine grained sandstone near base of unit; unit is thin to thick bedded and moderately resistant.	16.0	914.6
	Covered	11.7	898.6
11-441	Sandstone; calcareous, silty in part, dark grey, brown to red brown weathering, cross-laminated; minor, calcareous, dark grey, dark grey to grey weathering siltstone occurs as interbeds throughout unit; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	18.3	886.6
11-442	Siltstone and minor claystone; siltstone is calcareous in part, dark grey, dark grey weathering; grades to very fine grained sandstone at top of unit; claystone is dark grey, dark grey to black weathering, silty and occurs as interbeds throughout unit; unit is laminated to very thin bedded and moderately recessive.	14.8	868.6
	Covered	6.7	853.8
11-443	Coal and minor claystone; coal is hard, bright and blocky; claystone is silty and occurs near middle of unit.	12.1	847.1
11-444	Sandstone; silty, slightly calcareous, grey, light grey to brown weathering; minor siltstone occurs at top and near base of unit; unit is medium bedded, resistant and has a gradational lower contact.	6.7	835.0

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-445	Siltstone with minor sandstone and claystone; siltstone is dark grey, grey weathering, cross-laminated; sandstone is slightly calcareous, very fine grained, dark grey to grey, grey to red brown weathering and occurs near base of unit; claystone is dark grey, grey to dark grey weathering and occurs near top of unit; unit is laminated to thin bedded, moderately resistant and has a gradational lower contact.	11.0	828.3
11-446	Siltstone, calcareous, grey to dark grey, brown to red brown weathering, cross-laminated; unit is medium bedded, moderately resistant and has a gradational lower contact.	3.0	817.3
11-447	Claystone and minor siltstone; claystone is dark grey, grey to dark grey weathering; siltstone is calcareous in part, dark grey, grey to red brown weathering and occurs as interbeds throughout unit; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	7.7	814.3
11-448	Sandstone; calcareous, very fine to fine grained, grey to dark grey, grey to grey brown weathering, cross-laminated; grades to siltstone at base of unit; unit is laminated to thin bedded, moderately resistant and has a gradational lower contact.	18.0	806.6
11-449	Claystone, calcareous, silty, dark grey, dark grey weathering; minor interbeds of siltstone are present throughout unit; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	8.8	788.6
11-450	Sandstone; silty, calcareous, very fine grained, grey to dark grey, brown to grey brown weathering, cross-laminated; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	5.8	779.8
11-451	Siltstone; calcareous, carbonaceous in part, dark grey, grey weathering, unit is laminated, moderately recessive and has a gradational lower contact.	2.5	774.0
11-452	Coal with minor claystone; claystone is carbonaceous, dark grey, dark grey weathering and occurs in middle of seam.	4.3	771.5
11-453	Claystone; carbonaceous, dark grey, dark grey weathering, silty in part; unit is very thin to thin bedded, recessive and has a gradational lower contact.	6.2	767.2
11-454	Claystone and coal; claystone is silty, carbonaceous, dark grey, dark grey to black weathering; coal occurs in a seam 60 centimeters thick at top of unit; unit is laminated and recessive.	3.9	761.0

Unit No.	Description	Thickness (Feet)	Feet Above Base
	Covered	4.3	757.1
11-455	Claystone; carbonaceous, dark grey, dark grey to black weathering; unit is laminated, recessive and has a gradational lower contact.	4.1	752.8
11-456	Sandstone; slightly calcareous, very fine to fine grained, dark grey, brown to grey brown weathering, cross-laminated; unit is laminated to very thin bedded, moderately resistant and has a gradational lower contact.	1.8	748.7
11-457	Claystone; carbonaceous, dark grey, black to grey brown weathering; unit is laminated, recessive and has a gradational lower contact.	2.0	746.9
11-458	Sandstone; silty, calcareous, grey to dark grey, brown to light brown weathering, cross-laminated; unit is thin to medium bedded, moderately resistant and has a sharp conformable lower contact.	1.4	744.9
11-459	Siltstone with minor claystone; siltstone is calcareous, dark grey, dark grey weathering, sandy in part, grades to very fine grained sandstone near base; minor silty, calcareous, dark grey, dark grey weathering claystone occurs as interbeds dispersed throughout unit; unit is laminated to very thin bedded and has a sharp conformable lower contact.	2.5	743.5
11-460	Siltstone; very calcareous, dark grey, grey to grey brown weathering; minor, silty, calcareous claystone occurs near base of unit; unit is very thin bedded, moderately resistant and has a gradational lower contact.	2.5	741.0
11-461	Sandstone and minor siltstone; sandstone is slightly calcareous, very fine to fine grained, dark grey, grey weathering; minor siltstone and silty claystone occurs near base of unit; unit is laminated to very thin bedded, moderately resistant and has a gradational lower contact.	20.6	738.5
11-462	Siltstone; calcareous, grey to dark grey, grey to grey brown weathering; grades to very fine grained sandstone in places; minor, silty, dark grey, dark grey to black weathering claystone occurs near middle of unit; unit is laminated to thin bedded, moderately resistant and has a gradational lower contact.	10.5	717.9
11-463	Sandstone; slightly calcareous, very fine to fine grained, grey, grey to grey brown weathering, cross-laminated, unit is medium to thick bedded, resistant and has a gradational lower contact.	12.6	707.4
11-464	Sandstone; slightly calcareous, medium grained, dark grey, grey to grey brown weathering, cross-bedded;	10.0	694.8

Unit No.	Description	Thickness (Feet)	Feet Above Base
	unit is medium bedded, resistant and has a sharp faulted lower contact.		
11-465	Sandstone; calcareous in part, silty, fine medium grained, dark grey to grey, grey to grey brown weathering; unit is medium bedded, moderately resistant and has a gradational lower contact.	10.1	684.8
11-466	Siltstone and minor sandstone; siltstone is dark grey, grey to dark grey weathering; sandstone is calcareous, very fine to fine grained, grey, grey weathering; minor silty, dark grey, grey to dark grey weathering claystone occurs as interbeds throughout unit; unit is laminated to thin bedded, moderately recessive and has a gradational lower contact.	4.8	674.7
11-467	Sandstone; slightly calcareous in part, fine to medium grained, dark grey, grey weathering; unit is medium to thick bedded, resistant and has a gradational lower contact.	16.2	669.9
11-468	Sandstone; fine to coarse grained, slightly calcareous, grey, grey weathering, cross-bedded; unit is medium to thick bedded, resistant and has a sharp locally disconformable lower contact.	14.2	653.7
11-469	Siltstone with minor sandstone; siltstone is slightly calcareous, dark grey, dark grey weathering; sandstone is slightly calcareous very fine grained, grey, grey weathering, cross-laminated and occurs as interbeds throughout unit; unit is laminated to thin bedded, moderately recessive and has a sharp conformable lower contact.	12.2	639.5
11-470	Sandstone; slightly calcareous, medium grained, grey, grey weathering; unit is medium to thick bedded, resistant and has a sharp conformable lower contact.	4.5	627.3
11-471	Claystone; carbonaceous, dark grey to black, dark grey to black weathering; unit is laminated, recessive and has a gradational lower contact.	2.0	622.8
11-472	Sandstone; slightly calcareous, very fine grained, dark grey, brown to grey brown weathering, cross-laminated; unit is thin to medium bedded and moderately resistant.	1.9	620.8
	Covered	5.0	618.9
11-473	Sandstone; calcareous in part, fine to medium grained, dark grey, grey weathering; minor, dark grey, grey weathering siltstone occurs at top and near base of unit; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	8.6	613.9
11-474	Claystone; dark grey, grey weathering; unit is laminated, recessive and has a gradational lower contact.	3.0	605.3

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-475	Sandstone; calcareous, very fine grained, dark grey to grey, grey to grey brown weathering; cross-laminated, minor silty, calcareous, dark grey, grey brown weathering claystone and siltstone occurs as interbeds in lower part of unit; unit is laminated to thin bedded, moderately resistant and has a gradational lower contact.	10.5	602.3
11-476	Claystone; silty near top of unit, dark grey, dark grey to light grey brown weathering; unit is laminated, moderately recessive and has a gradational lower contact.	6.0	591.8
11-477	Claystone with minor coal and sandstone; claystone is carbonaceous, dark grey, dark grey to black weathering; coal occurs in a 15 centimeter thick seam at top of unit and a 30 centimeter thick seam near base; minor fine grained, calcareous, grey, grey brown weathering sandstone occurs near middle of unit; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	5.6	585.8
11-478	Siltstone and minor claystone; siltstone is calcareous in part, dark grey, grey to grey brown weathering, cross-laminated and grades to very fine grained sandstone at base; claystone is dark grey, grey to grey brown weathering, silty near top of unit and occurs in top and middle of unit; unit is laminated to thin bedded, moderately recessive and has a gradational lower contact.	8.7	580.2
11-479	Claystone; calcareous in part, silty, carbonaceous, dark grey, grey to dark grey weathering; unit is laminated to very thin bedded, recessive and has a sharp conformable lower contact.	4.0	571.5
11-480	Sandstone with minor siltstone; sandstone is grey to dark grey, grey to red brown weathering, fine grained, cross-laminated; siltstone is calcareous, dark grey, grey to grey brown weathering and occurs near base of unit; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	5.0	567.5
11-481	Claystone; silty, dark grey, dark grey to grey brown weathering; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	4.1	562.5
11-482	Sandstone; slightly calcareous, very fine to medium grained, grey to dark grey, grey weathering, cross-laminated; unit is very thin to thin bedded and moderately resistant.	5.0	558.4
	Covered	7.5	553.4
11-484	Claystone; dark grey, dark grey to grey brown weathering, silty near top of unit; unit is laminated	4.2	545.9

Unit No.	Description	Thickness (Feet)	Feet Above Base
	to thin bedded, recessive and has a sharp conformable lower contact.		
11-485	Siltstone; calcareous, dark grey, yellow brown weathering; unit is medium to thick bedded, moderately resistant and has a gradational lower contact.	3.5	541.7
11-486	Claystone; carbonaceous in part, sandy, dark grey, dark grey to rusty brown weathering; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	9.3	538.2
11-487	Claystone with minor sandstone; claystone is calcareous in part, dark grey, dark grey to grey brown weathering, silty near top of unit; sandstone is calcareous, very fine grained, dark grey, grey brown weathering and occurs at top of unit; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	12.7	528.9
11-488	Sandstone; slightly calcareous, very fine to fine grained, grey, grey brown weathering, cross-laminated, becomes silty near top of unit; unit is medium to thick bedded, resistant and has a sharp conformable lower contact.	3.5	516.2
11-489	Siltstone; calcareous, dark grey, grey to red brown weathering, grades to very fine grained sandstone at top of unit; minor silty, dark grey, dark grey to grey brown weathering claystone occurs near base of unit and as interbeds throughout unit; unit is laminated to very thin bedded, moderately recessive and has a sharp conformable lower contact.	4.2	512.7
11-490	Sandstone; calcareous, fine grained, grey, grey brown weathering; minor cross-laminations; unit is thin to medium bedded, moderately resistant and has a sharp conformable lower contact.	4.4	508.5
11-491	Sandstone with minor siltstone and claystone; sandstone is very fine grained, calcareous, dark grey to brown, dark grey to brown weathering, cross-laminated; siltstone and claystone are calcareous, dark grey, dark grey to grey brown weathering and occurs near base of unit; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	14.0	504.1
11-492	Siltstone; calcareous, dark grey, dark grey to red brown weathering, grades to very fine grained sandstone at base of unit; unit is laminated to very thin bedded and moderately recessive.	7.5	490.1
11-493	Coal; bright, blocky, hard.	4.7	482.6
11-494	Claystone; dark grey to black, dark grey to black weathering, carbonaceous near base, silty in part; unit is laminated, recessive and has a gradational	11.4	477.9

Unit No.	Description	Thickness (Feet)	Feet Above Base
	lower contact.		
11-495	Siltstone; very calcareous, dark grey to grey, yellow brown weathering; unit is thin bedded, moderately resistant and has a gradational lower contact.	1.8	466.5
11-496	Siltstone; calcareous, dark grey, grey to grey brown weathering, grades to very fine grained sandstone in places; unit is very thin to thin bedded, moderately recessive and has a gradational lower contact.	4.1	464.7
11-497	Claystone and minor coal; claystone is carbonaceous, dark grey to black, dark grey to black weathering; coal occurs in a 50 centimeter thick seam at base of unit; unit is laminated to very thin bedded, recessive and has a sharp conformable lower contact.	20.0	460.6
11-498	Sandstone, calcareous, silty near base, dark grey to grey, grey to grey brown weathering, cross-laminated; unit is thin to medium bedded, moderately resistant and has a gradational lower contact.	5.0	440.6
11-499	Claystone and minor siltstone; claystone is carbonaceous, dark grey, black to grey brown weathering; siltstone is slightly calcareous, dark grey, dark brown weathering and occurs as interbeds dispersed throughout unit; unit is laminated to very thin bedded moderately recessive and has a sharp conformable lower contact.	8.8	435.6
11-500	Siltstone; calcareous, dark grey. yellow to yellow brown weathering; unit is medium to thick bedded, resistant and has a sharp conformable lower contact.	2.1	426.8
11-501	Claystone and minor siltstone; claystone is carbonaceous, dark grey, dark grey to black weathering; grades to siltstone in places; unit is laminated, recessive and has a gradational lower contact.	4.9	424.7
11-502	Sandstone; calcareous, very fine grained, dark grey, grey brown to yellow weathering, cross-laminated; unit is thin to thick bedded, resistant and has a gradational lower contact.	4.8	419.8
11-503	Claystone; carbonaceous near middle of unit, dark grey, dark grey to grey brown weathering; grades to siltstone near top and at base of unit; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	4.1	415.0
11-504	Sandstone; calcareous, fine to medium grained, grey, grey to grey brown weathering; unit is medium bedded, moderately resistant and has a gradational lower contact.	1.8	410.9
11-505	Siltstone and minor sandstone; siltstone is calcareous in part, dark grey, dark grey to dark brown	28.6	409.1

Unit No.	Description	Thickness (Feet)	Feet Above Base
	weathering; grades to very fine grained sandstone near top of unit; unit is laminated to thin bedded, moderately recessive and has a gradational lower contact.		
11-506	Sandstone; calcareous, dark grey to grey, grey to grey brown weathering, very fine grained; grades to siltstone at top and at base of unit; unit is very thin to thin bedded, moderately resistant and has a sharp conformable lower contact.	7.4	380.5
11-507	Coal; bright and moderately blocky.	5.4	373.1
11-508	Siltstone and minor claystone and sandstone; siltstone is carbonaceous, dark grey, dark grey to grey weathering, cross-laminated; grades to very fine grained sandstone near top of unit and carbonaceous claystone near base; unit is very thin to thin bedded, moderately recessive and has a gradational lower contact.	21.7	367.7
11-509	Sandstone; calcareous, very fine to medium grained, grey to dark grey, grey to red brown weathering, cross-laminated; unit becomes finer grained near base; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	11.4	346.0
11-510	Claystone and minor siltstone; claystone is carbonaceous, dark grey to black, dark grey to black weathering; siltstone is slightly carbonaceous, dark grey, dark grey to dark brown weathering and occurs near top of unit; unit is laminated, recessive and has a gradational lower contact.	7.1	334.6
11-511	Sandstone; slightly calcareous, fine to medium grained, grey to dark grey, grey to grey brown weathering, cross-laminated; unit is thin to thick bedded, resistant and has a gradational lower contact.	17.3	327.5
11-514	Siltstone; and minor claystone; siltstone is calcareous, dark grey, dark grey to rusty brown weathering; grades to very fine grained sandstone near top of unit and to claystone near base; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	24.5	310.2
11-515	Sandstone; slightly calcareous, silty in part, very fine grained, dark grey, grey weathering, cross-laminated; grades to siltstone near base; unit is laminated, moderately resistant and has a gradational lower contact.	5.5	285.7
11-516	Claystone and minor siltstone; claystone is carbonaceous, dark grey, dark grey to black weathering; grades to siltstone at base; siltstone is dark grey and grey to rusty brown weathering; unit is laminated to very thin bedded, recessive and has a	9.0	280.2

Unit No.	Description	Thickness (Feet)	Feet Above Base
	gradational lower contact.		
11-517	Sandstone; slightly calcareous, silty near top of unit, dark grey, dark brown to rusty brown weathering, very fine to medium grained; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	8.6	271.2
11-518	Claystone and minor siltstone; claystone is dark grey, dark grey to grey weathering; siltstone is calcareous, dark grey, grey weathering and occurs as interbeds dispersed throughout unit; unit is laminated, moderately recessive and has a gradational lower contact.	4.8	262.6
11-519	Sandstone, very fine to fine grained, dark grey to brown, grey to brown weathering; unit is very thin bedded, moderately resistant and has a gradational lower contact.	0.9	257.8
11-520	Siltstone; slightly calcareous, dark grey, grey to dark grey weathering; grades to very fine grained sandstone near top of unit and becomes carbonaceous near base; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	10.2	256.9
11-521	Coal; hard, blocky, bright.	14.8	246.7
11-522	Siltstone; dark grey, grey weathering, cross-laminated; grades to very fine grained sandstone at base of unit; unit is thin bedded, moderately resistant and has a gradational lower contact.	4.8	231.9
11-523	Siltstone; dark grey, dark grey weathering, cross-laminated; grades to very fine grained sandstone near middle of unit; unit is laminated to thin bedded, moderately recessive and has a gradational lower contact.	4.8	227.1
11-524	Sandstone; slightly calcareous, dark grey to dark brown, grey to rusty brown weathering, very fine to fine grained, cross-laminated; unit is thin to medium bedded and moderately resistant.	4.7	222.3
	Covered	8.5	217.6
11-525	Claystone and minor siltstone; claystone is slightly calcareous, dark grey, dark grey weathering; siltstone is calcareous in part, dark grey, dark grey to rusty brown weathering and occurs near middle and at base of unit; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	15.8	209.1
11-526	Claystone; dark grey, dark grey to brown weathering, becomes silty towards base; unit is laminated to very thin bedded, moderately resistant and has a gradational lower contact.	6.5	193.3

Unit No.	Description	Thickness (Feet)	Feet Above Base
11-527	Siltstone; calcareous in part, dark grey, grey to rusty brown weathering; grades to very fine grained sandstone near middle of unit; minor dark grey, dark grey to grey weathering, silty claystone occurs near top of unit; unit is laminated to thin bedded, moderately resistant and has a gradational lower contact.	27.0	186.8
11-528	Sandstone; calcareous, dark grey, grey to grey brown weathering, very fine to fine grained, becomes coarser grained near base of unit; unit is very thin to medium bedded and moderately resistant.	18.5	159.8
	Covered	91.8	141.3
	Base of interbedded sandstone, siltstone and shale unit.		
11-529	Sandstone; slightly calcareous at base of unit, light grey, grey to dark grey weathering, cross-bedded; unit is medium to thick bedded, resistant and has a sharp apparently conformable lower contact.	49.5	
	Total Thickness of Kootenay Formation		3801.2
	Fernie Formation		
11-530	Sandstone; calcareous, fine to medium grained, dark grey, light grey to brown weathering, cross-laminated, sandstone exhibits parting nearly perpendicular to bedding; unit is thick bedded and less resistant than unit 11-529.	24.5	
	Total Thickness of Fernie Strata Measured		24.5

WIND RIDGE SECTION

Location - on south-east facing slope of Wind Ridge beginning at summit in Section 2, Township 24, Range 10, West of the 5th Meridian.

Unit No.	Description	Thickness (Feet)	Feet Above Base
	Blairmore Group (Gladstone Formation)		
09-01	Sandstone and minor conglomerate; sandstone is medium to very coarse grained, calcareous, dark brown, light brown weathering, cross-bedded; conglomerate contains clasts up to 1 inch in diameter, clasts sub angular, occurs in 5 foot bed at middle of unit, unit is thin to medium bedded and moderately resistant.	35.0	247.3
	Covered	10.0	212.3
09-02	Sandstone; very fine to fine grained grading to coarse grained at base of unit, calcareous, dark grey, dark grey weathering, cross-laminated; unit is thin bedded, moderately resistant and has a gradational lower contact.	7.5	202.3
09-03	Conglomerate and minor sandstone; conglomerate contains well rounded clasts up to 3 inches in diameter, average diameter 1 and ½ inches, large proportion of black chert clasts, grey to grey brown, weathers grey; sandstone is coarse to very coarse grained, dark brown, light brown weathering and occurs as interbeds dispersed throughout unit; unit is medium to very thick bedded, resistant and has a sharp conformable lower contact.	27.5	194.8
09-04	Sandstone and conglomerate; sandstone is medium to very coarse grained, calcareous, dark grey, brown to light brown weathering, cross-bedded; conglomerate contains clasts up to 2 inches in diameter, dark grey, weathers grey, occurs in a bed just below middle of unit and as interbeds dispersed throughout unit; unit is thin to medium bedded and resistant.	17.0	167.3
	Covered	5.0	150.3
09-05	Sandstone and minor conglomerate; sandstone is medium to very coarse grained, slightly calcareous, pebbly in part, brown, light brown weathering, cross-bedded; conglomerate contains clasts to 1 inch in diameter and occurs at base and near middle of unit, dark grey, grey weathering; unit is thin to thick bedded and moderately resistant.	19.0	145.3
	Covered	23.0	126.3
09-06	Sandstone, medium to very coarse grained, becomes coarser grained near base, slightly calcareous,	22.8	103.3

Unit No.	Description	Thickness (Feet)	Feet Above Base
	pebbly near base, grey, grey to dark brown weathering, cross-bedded; unit is medium to thick bedded, resistant and has a sharp conformable lower contact.		
09-07	Conglomerate; contains clasts to 3 inches in diameter, average diameter about 1½ to 2 inches, large proportion of black chert clasts, dark grey, dark grey to grey weathering; unit is medium to thick bedded, resistant and has a sharp, locally disconformable lower contact.	12.7	81.3
09-08	Sandstone; medium to very coarse grained, calcareous, grey brown, brown weathering, cross-bedded; unit is thin to medium bedded, resistant and has a gradational lower contact.	4.8	68.6
09-09	Conglomerate; clasts up to 2½ inches in diameter, average about 1½ inches, dark grey, grey weathering; unit is medium to thick bedded, resistant and has a sharp lower contact.	10.8	64.6
09-10	Sandstone; coarse to very coarse grained, pebbly in part, slightly calcareous, grey, dark brown weathering, cross-bedded; unit is thin to medium bedded, resistant and has a gradational lower contact.	2.7	53.8
09-11	Conglomerate; sandy in part, clasts up to 2 inches in diameter, average about 1 inch, dark grey to brown, grey weathering, grades to very coarse grained pebbly sandstone at top of unit; unit is medium to very thick bedded, resistant and has a sharp lower contact.	17.5	51.1
09-12	Conglomerate and sandstone; conglomerate contains clast up to 5 inches in diameter, average between 1 and 1½ inches in diameter, grey to dark grey, grey weathering; minor coarse grained, dark grey, grey weathering sandstone occurs as interbeds dispersed throughout unit and a bed of fine to medium grained, calcareous, grey brown, light brown weathering, cross-laminated sandstone occurs at base of unit; unit is thin to very thick bedded, resistant and has a gradational lower contact.	18.9	33.2
09-13	Conglomerate; contains clasts up to 6 inches in diameter, average between 1 and 1½ inches in diameter, large proportion of smaller clasts are black chert, grey to dark grey, grey weathering; minor coarse grained, grey brown, brown to light brown weathering sandstone occurs as interbeds dispersed throughout unit; unit is thick to very thick bedded, resistant and has a gradational lower contact.	14.3	14.3

Unit No.	Description	Thickness (Feet)	Feet Above Base
	Blairmore - Kootenay contact from cross-correlation		
	Total thickness of Blairmore Strata		
	Kootenay Formation		
09-14	Sandstone and minor claystone; sandstone is medium to very coarse grained, slightly calcareous, dark grey to brown, brown weathering, cross-bedded; claystone is silty, dark grey, dark grey weathering and occurs near middle of unit; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	5.3	265.1
09-15	Conglomerate; contains clasts to 6 inches in diameter, average about 2 to 3 inches, clast size becomes larger near base, grey, grey weathering; contains minor, coarse grained, grey brown, dark brown weathering sandstone interbeds dispersed throughout unit; unit is thick to very thick bedded, resistant and has a gradational lower contact.	19.3	259.8
09-16	Conglomerate and sandstone; conglomerate contains clasts to 1 inch in diameter, average between ½ and 3/4 of an inch in diameter, dark grey to brown, grey brown weathering; coarse grained, brown, light brown weathering, calcareous, cross-bedded sandstone occurs as interbeds dispersed throughout unit, and a bed of medium grained, calcareous, grey, light brown weathering sandstone occurs near middle of unit; unit is thin to very thick bedded and resistant.	38.0	240.5
	Covered	15.0	202.5
09-17	Sandstone and siltstone; sandstone is medium to very coarse grained, dark grey, grey to dark grey weathering; cross-laminated siltstone is dark grey, dark grey weathering and occurs near top of unit; unit is very thin to medium bedded, moderately resistant and has a sharp conformable lower contact.	15.2	187.5
09-18	Sandstone; very fine to coarse grained, calcareous, dark grey, brown to light brown weathering, cross-laminated; unit is very thin to medium bedded and moderately resistant.	31.0	172.3
	Covered	9.3	141.3
09-19	Siltstone; carbonaceous, dark grey, dark grey weathering; unit is laminated to very thin bedded and recessive.	1.3	132.0
	Covered	5.0	130.7
09-20	Sandstone and siltstone; sandstone is very fine to fine grained, calcareous, dark grey to brown,	22.1	125.7

Unit No.	Description	Thickness (Feet)	Feet Above Base
	light brown weathering, cross-laminated; siltstone is calcareous, dark grey, grey weathering and occurs near top of unit; unit is laminated to thin bedded, moderately recessive and has a sharp conformable lower contact.		
09-21	Sandstone; very coarse grained, calcareous, dark grey, brown weathering, cross-bedded; unit is medium bedded, resistant and has a sharp conformable lower contact.	3.6	103.6
09-22	Conglomerate; contains clasts to 1½ inches in diameter, average about 3/4 inch in diameter, dark grey to grey, grey to dark grey weathering, sandy in part; unit is medium to thick bedded, resistant and has a sharp disconformable lower contact.	4.2	100.0
09-23	Sandstone; coarse to very coarse grained, slightly calcareous, dark grey, light brown to brown weathering, cross-bedded; unit is medium bedded, moderately resistant and has a sharp disconformable lower contact.	3.3	95.8
09-24	Sandstone; very fine to medium grained, slightly calcareous, dark grey, light brown weathering, becomes finer grained near top of unit; unit is moderately recessive and has a sharp locally disconformable lower contact.	2.2	92.5
09-25	Conglomerate; clasts to 1½ inches, average about 3/4 of an inch, grey, grey weathering; unit is thick to very thick bedded and resistant.	10.0	90.3
	Covered	5.0	80.3
09-26	Sandstone and siltstone; sandstone is calcareous, silty, very fine grained, dark brown, grey brown weathering, cross-laminated; siltstone is dark grey, dark grey weathering and occurs at top and near base of unit; unit is thin to medium bedded, moderately recessive and has a gradational lower contact.	10.7	75.3
09-27	Siltstone and claystone; siltstone is slightly calcareous, sandy in part, dark grey, brown to light brown weathering; claystone is dark grey, dark grey to brown weathering, silty and occurs dispersed throughout unit; unit is laminated to thin bedded, moderately recessive and has a gradational lower contact.	17.8	64.6
09-28	Sandstone and siltstone; sandstone is very fine to fine grained, calcareous, dark grey, light brown weathering, cross-laminated; siltstone is slightly calcareous, grey, light brown weathering and occurs near base of unit; unit is very thin to thin bedded and moderately resistant.	4.6	46.8

Unit No.	Description	Thickness (Feet)	Feet Above Base
	Covered	8.6	42.2
09-29	Claystone; silty, dark grey, dark grey to brown weathering, cross-laminated; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	1.6	33.6
09-30	Sandstone; very fine to medium grained, slightly calcareous, silty in part, dark brown, light brown weathering, cross-laminated; unit is laminated to thin bedded, moderately resistant and has a gradational lower contact.	7.5	32.0
09-31	Sandstone; calcareous, fine to medium grained, dark brown to grey, light brown weathering, cross-bedded; unit is thin to medium bedded and resistant.	24.5	24.5
	Total Thickness of Kootenay Strata Measured		265.1
	Total Thickness of Strata Measured		512.4

THREE SISTERS SECTION

Location - On a north east facing slope just east of The Three Sisters in the south west corner of Section 10, Township 24, Range 10, West of the 5th Meridian.

Unit No.	Description	Thickness (Feet)	Feet Above Base
	Kootenay Formation		
06-43	Siltstone; calcareous, dark grey, dark brown to grey weathering, sandy in part; unit is laminated to thin bedded, moderately resistant and has a gradational lower contact.	12.7	529.7
06-42	Siltstone; calcareous, dark grey, brown yellow weathering, massive; unit is very thin to thin bedded, moderately resistant and has a gradational lower contact.	6.0	517.0
06-41	Siltstone; shaly in part; slightly calcareous, dark grey, dark grey weathering; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	1.6	511.0
06-40	Sandstone; silty in part, slightly calcareous, very fine to fine grained, dark grey, rusty brown to yellow weathering, cross-laminated; unit is thin to thick bedded, resistant and has a gradational lower contact.	9.2	509.4
06-39	Claystone; slightly calcareous, silty, dark grey, dark grey to red brown weathering, grades to siltstone near top of unit, minor carbonaceous partings near base; unit is very thin to thin bedded, moderately resistant and has sharp conformable lower contact.	4.5	500.2
06-38	Sandstone; very fine to fine grained, calcareous, silty, brown, brown weathering, cross-laminated; unit is thin to medium bedded, resistant and has a gradational lower contact.	3.6	495.7
06-37	Claystone; carbonaceous, dark grey, dark grey weathering; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	4.4	492.1
06-36	Siltstone; calcareous, dark grey, light brown to yellow weathering, grades to very fine grained sandstone near top, cross-laminated; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	6.2	487.7
06-35	Claystone; carbonaceous, dark grey, dark grey to rusty brown weathering, grades to siltstone in places; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	3.7	481.5

Unit No.	Description	Thickness (Feet)	Feet Above Base
06-34	Sandstone; slightly calcareous, very fine to fine grained, silty, dark grey to grey, rusty brown weathering, cross-laminated; minor claystone occurs at top and near base of unit; unit is thin to medium bedded, resistant and has a gradational lower contact.	5.0	477.8
06-33	Claystone and minor coal; claystone is carbonaceous, dark grey, dark grey weathering and contains numerous plant remains; coal occurs in 25 centimeter thick seam near middle of unit; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	5.7	472.8
06-32	Sandstone; very fine to fine grained, slightly calcareous, silty in part, dark brown, rusty brown weathering, cross-laminated; unit is very thin to thick bedded, resistant and has a gradational lower contact.	13.7	467.1
06-31	Coal with minor carbonaceous claystone partings.	5.0	453.4
06-30	Claystone; slightly calcareous, dark grey, dark grey to brown weathering; unit is thinly laminated to very thin bedded, recessive and has a gradational lower contact.	4.3	448.4
06-29	Sandstone and minor siltstone; sandstone is very fine grained, grey brown, rusty brown weathering; siltstone is slightly calcareous, dark grey, red brown weathering and occurs at top of unit; unit is very thin to medium bedded, resistant and has a gradational lower contact.	7.1	444.1
06-28	Coal	1.0	437.0
06-27	Siltstone; dark grey, grey weathering, shaly in part; unit is laminated to thin bedded, recessive and has a gradational lower contact.	1.4	436.0
	Covered	4.8	434.6
06-26	Claystone and minor siltstone; claystone is carbonaceous, dark grey, grey to red brown weathering; siltstone is slightly calcareous, dark grey, grey weathering and occurs near middle of unit; unit is laminated to very thin bedded, moderately recessive and has a gradational lower contact.	3.2	429.8
06-25	Sandstone; slightly calcareous, silty in part, very fine grained, dark grey, grey brown weathering, minor siltstone bands occur dispersed throughout unit; unit is very thin to medium bedded, moderately resistant and has a gradational lower contact.	5.3	426.6
06-24	Claystone; dark grey, dark grey weathering, minor coaly partings; unit is laminated to very thin bedded, recessive and has a gradational lower contact.	4.8	421.3

Unit No.	Description	Thickness (Feet)	Feet Above Base
06-23	Coal with minor claystone interbeds.	3.3	416.5
06-22	Siltstone; calcareous, sandy in part, dark grey, yellow brown weathering; unit is laminated to thin bedded, moderately resistant and has a gradational lower contact.	2.4	413.2
06-21	Claystone; carbonaceous in part, dark grey to black, dark grey to brown weathering, coaly partings at base and near middle of unit; unit is laminated to thin bedded, moderately recessive and has a sharp conformable lower contact.	8.3	410.8
06-20	Sandstone; slightly calcareous, silty in part, very fine to fine grained, grey to light brown, rusty brown weathering, cross-laminated; unit is thin to medium bedded, resistant and has a gradational lower contact.	10.7	402.5
06-19	Sandstone; slightly calcareous, silty, very fine grained, dark grey, grey to brown weathering; unit is very thin to thin bedded, moderately recessive and has a gradational lower contact.	4.1	391.8
06-18	Sandstone; calcareous, very fine grained, grey, light rusty brown weathering; unit is thick bedded, resistant and has a gradational lower contact.	3.1	387.7
06-17	Claystone; silty in part, dark grey, dark brown to rusty brown weathering, minor coal seam 15 centimeters thick occurs at top of unit; unit is very thin to thin bedded, moderately recessive and has a gradational lower contact.	3.1	384.6
06-16	Sandstone; calcareous, silty, very fine grained, grey to dark brown, light brown weathering; unit is thin bedded, resistant and has a gradational lower contact.	11.0	381.5
06-15	Siltstone; sandy, slightly calcareous, grades to very fine grained sandstone at top of unit and claystone at base, dark grey, dark grey to brown weathering; unit is laminated to thin bedded, moderately resistant and has a gradational lower contact.	1.2	370.2
06-14	Coal with minor claystone partings.	4.2	369.3
06-13	Siltstone; slightly calcareous, dark grey, grey brown weathering; unit is very thin to thin bedded, moderately recessive and has a gradational lower contact.	0.9	365.1
06-12	Coal	1.1	364.2
06-11	Sandstone; calcareous, very fine to fine grained, dark brown to brown, rusty brown weathering, cross-laminated; unit is thin to thick bedded, resistant and has a sharp conformable lower contact.	20.0	363.1

Unit No.	Description	Thickness (Feet)	Feet Above Base
06-10	Claystone and minor coal; claystone is silty, dark grey, grey to rusty brown weathering and grades to siltstone in places; unit is very thin to thin bedded and has a gradational lower contact.	5.7	343.1
06-09	Sandstone; calcareous, silty, very fine grained, dark brown, rusty brown weathering, cross-laminated; unit is thin bedded, resistant and has a gradational lower contact.	3.2	337.4
06-08	Claystone; silty, calcareous, dark grey, grey weathering; minor very fine grained, silty, dark brown, light red brown weathering sandstone occurs at base of unit; unit is very thin bedded, moderately recessive and has a gradational lower contact.	4.5	334.2
06-07	Sandstone; silty, calcareous, dark grey to brown, light brown weathering, cross-laminated; unit is resistant and has a gradational lower contact.	5.6	329.7
06-06	Siltstone and minor sandstone; siltstone is slightly calcareous, dark grey, light grey weathering; sandstone is very fine grained, silty, dark brown, light brown weathering and occurs near top of unit, cross-laminated; unit is thinly laminated to laminated, moderately recessive and has a gradational lower contact.	4.3	324.1
06-05	Sandstone; silty, calcareous, very fine grained, dark grey, brown weathering, cross-laminated; unit is laminated to thinly laminated, moderately recessive and has a gradational lower contact.	2.0	319.8
06-04	Claystone; silty in part, dark grey, grey weathering; unit is very thin bedded, recessive and has a sharp conformable lower contact.	2.4	317.8
06-03	Sandstone; calcareous, very fine to fine grained, silty, dark brown, red brown weathering, cross-laminated, ripple marks evident on some bedding planes; unit is moderately resistant and has a sharp conformable lower contact.	8.9	315.4
	Covered	10.0	306.5
06-02	Siltstone; sandy in part, dark grey, dark brown to brown weathering, grades to very fine grained sandstone near top and claystone near base of unit; unit is laminated to very thin bedded, moderately recessive and has a sharp conformable lower contact.	6.5	296.5
06-01	Siltstone; slightly calcareous, dark grey, dark grey weathering; unit is laminated to thinly laminated, recessive and has a gradational lower contact.	1.5	290.0

Unit No.	Description	Thickness (Feet)	Feet Above Base
05-09	Sandstone; calcareous, very fine grained, silty, dark grey to brown; brown weathering, cross-laminated; unit is very thin to thin bedded and moderately resistant.	3.0	288.5
	Covered	10.0	285.5
05-08	Sandstone; silty, slightly calcareous, very fine grained, dark grey, dark brown weathering, cross-laminated; unit is very thin bedded and moderately resistant.	7.5	275.5
	Covered	10.0	268.0
05-07	Sandstone; very fine to fine grained, slightly calcareous, dark brown, light brown weathering, cross-laminated, grades to claystone near top of unit; unit is very thin bedded, moderately resistant and has a gradational lower contact.	5.5	258.0
05-06	Claystone; carbonaceous, dark grey, grey to light brown weathering; unit is laminated and moderately recessive.	3.0	252.5
	Covered	85.0	249.5
05-05	Sandstone; very fine grained, silty, calcareous, grey, brown weathering, cross-laminated; unit is laminated and moderately resistant.	2.0	164.5
	Covered	105.0	162.5
05-04	Sandstone; very fine to fine grained, calcareous, dark grey, brown weathering, cross-laminated; unit is laminated and moderately resistant.	2.0	57.7
	Covered	24.0	55.7
05-03	Claystone; silty in part, dark grey, weathers grey to dark brown; unit is thinly laminated and recessive.	8.0	31.7
05-02	Sandstone; very fine grained, dark grey, red brown weathering, slightly calcareous; unit is laminated, moderately resistant and has a gradational lower contact.	1.7	23.7
05-01	Coal	7.0	22.0
	Covered	15.0	15.0
	Mount Rundle Fault		
	Total Thickness of Kootenay Strata Measured		527.7

Appendix B - Coded Sample Data

NB. - Variables are arranged in the order given in Figure 5 (p. 31). Refer to Figure 5 for the range in percent represented by each column for percentage-type data.

SAMPLE NUMBER	DEPTH	GRAIN SIZE 1 2 3 4 5 6 7 8 9 10 11	% MATRIX	% CEM	BK	% CHERT G	B	GN	WH	BK	% QUARTZITE G	B	WH	% PYR	% ROCK FRAGS	% CLASTIC CARBNT	% CARBNACOUS MATERIAL	L A M	SCL OF LAM	C L	G D	SCL ORD BEDS	CT BG	CP HO	RT ASC	COLOR FRESH BD L DG	COLOR WEATHERING BD L DGSRY	CA SV	RND ARR	ST PA	P
[illegible]	.5	[illegible]	2111111	211	22111	11	1	111	11	111	22111	111	111	111	21111	2111111	111111111	2	121	1	1	1111	11	11	111	1112111	112111111	11	211	21	1
[illegible]	5.5	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2111111	111111111	2	121	1	1	1111	11	11	111	1112111	112111111	21	211	21	1
[illegible]	10.0	[illegible]	2211111	211	22111	11	1	111	11	111	11111	111	111	111	21111	2111111	111111111	2	112	1	2	1112	11	11	111	1112111	112111111	11	211	21	1
[illegible]	14.2	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2111111	111111111	1	111	1	1	1111	11	11	111	1112111	112111111	11	211	21	1
[illegible]	17.7	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2221111	111111111	2	112	1	2	1112	11	11	111	1112111	112111111	21	211	21	1
[illegible]	20.1	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2222111	111111111	1	111	1	1	1111	11	11	111	1111111	112111111	22	211	11	1
[illegible]	30.5	[illegible]	2221111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2111111	111111111	1	111	1	1	1111	11	11	111	1112111	112111111	21	221	21	1
[illegible]	35.5	[illegible]	2111111	211	22111	11	1	111	11	111	11111	111	111	111	21111	2211111	111111111	2	121	1	1	1111	11	11	111	1111112	112111111	22	221	12	1
[illegible]	44.0	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	21111	1111111	111111111	1	111	1	1	1111	11	11	111	1112111	112111111	11	211	12	1
[illegible]	47.5	[illegible]	2111111	211	11111	11	1	111	11	111	11111	111	111	111	21111	2221111	111111111	2	111	0	1	1111	11	11	111	1112111	112111111	21	221	12	1
[illegible]	51.0	[illegible]	2111111	211	22111	11	1	111	11	111	11111	111	111	111	21111	2211111	111111111	2	211	1	1	1111	11	11	111	1121111	112111111	21	211	12	1
[illegible]	61.7	[illegible]	2111111	211	22111	11	1	111	11	111	11111	111	111	111	21111	1111111	111111111	2	121	1	1	1111	11	11	111	1211111	112111111	11	211	21	1
[illegible]	62.2	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2221111	111111111	1	121	1	1	1111	11	11	111	1121111	112111111	21	221	11	1
[illegible]	66.0	[illegible]	2211111	221	22111	11	1	111	11	111	22111	111	111	111	22111	2221111	111111111	2	121	1	1	1111	11	11	111	1121111	112111111	22	211	11	1
[illegible]	74.0	[illegible]	2221111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2211111	111111111	1	111	1	1	1111	11	11	111	1121111	111111121	21	221	11	1
[illegible]	83.7	[illegible]	2211111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2211111	111111111	1	111	1	1	1111	11	11	111	1121111	112111111	21	221	11	1
[illegible]	92.2	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2211111	111111111	1	111	1	1	1111	11	11	111	1111112	112111111	21	211	11	1
[illegible]	95.5	[illegible]	2111111	211	11111	11	1	111	11	111	11111	111	111	111	21111	2211111	111111111	2	121	1	1	1111	11	11	111	1111211	112111111	21	221	21	1
[illegible]	96.0	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2211111	111111111	1	111	1	1	1111	11	11	111	1111211	111111111	21	211	12	1
[illegible]	100.0	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2221111	111111111	1	111	1	1	1111	11	11	111	1121111	112111111	21	211	21	1
[illegible]	102.0	[illegible]	2221111	211	22111	11	1	111	11	111	11111	111	111	111	21111	2211111	111111111	1	111	1	1	1111	11	11	111	1121111	112111111	21	221	11	1
[illegible]	106.0	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2211111	111111111	2	211	1	1	1111	11	11	111	1121111	112111111	21	211	11	1
[illegible]	110.0	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2221111	111111111	2	211	1	1	1111	11	11	111	1121111	112111111	22	221	21	1
[illegible]	112.9	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2211111	111111111	1	111	1	1	1111	11	11	111	1112111	112111111	21	211	11	1
[illegible]	114.9	[illegible]	2111111	211	22211	11	1	111	11	111	11111	111	111	111	21111	2111111	111111111	1	111	1	1	1111	11	11	111	1111111	111211111	11	211	12	1
[illegible]	119.3	[illegible]	2222222	211	22111	11	1	211	11	111	22111	111	111	111	21111	1111111	111111111	1	111	1	1	1111	11	11	111	1121111	112111111	11	111	11	1
[illegible]	124.1	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2221111	111111111	2	121	1	1	1111	11	11	111	1111121	112111111	21	111	21	1
[illegible]	126.1	[illegible]	2111111	211	22111	11	1	121	11	111	11111	111	111	111	21111	2111111	111111111	1	111	1	1	1111	11	11	111	1121111	112111111	21	221	12	1
[illegible]	129.7	[illegible]	2111111	211	22111	11	1	111	11	111	11111	221	211	111	22111	1111111	111111111	1	111	1	1	1111	11	11	111	1121111	112111111	11	222	21	1
[illegible]	135.9	[illegible]	2111111	111	22111	11	1	211	11	111	11111	221	211	111	22111	1111111	111111111	1	111	1	1	1111	11	11	111	1121111	112111111	11	221	11	1
[illegible]	137.2	[illegible]	2111111	211	22111	11	1	111	11	111	22211	111	211	111	22111	2111111	111111111	1	111	1	1	1111	11	11	111	1121111	112111111	21	221	21	1
[illegible]	140.1	[illegible]	2111111	211	22111	11	1	211	11	111	21111	111	221	111	22111	2111111	111111111	1	111	1	1	1111	11	11	111	1121111	112111111	11	222	21	1
[illegible]	143.1	[illegible]	2222222	211	00000	00	0	000	00	000	00000	000	000	000	00000	0000000	000000000	1	111	1	1	1111	21	11	111	1121111	112111111	11	000	00	1
[illegible]	148.2	[illegible]	2222222	211	00000	00	0	000	00	000	00000	000	000	000	00000	0000000	000000000	1	111	1	1	1111	21	11	111	1121111	112111111	11	211	21	1
[illegible]	151.6	[illegible]	2222222	211	11111	22	1	211	21	111	22211	111	111	111	21111	1111111	111111111	1	111	1	1	1111	11	11	111	1121111	112111111	11	221	21	1
[illegible]	155.9	[illegible]	2222222	222	22111	11	1	221	11	111	11111	211	221	111	22111	1111111	211111111	1	111	1	1	1111	21	11	111	1121111	112111111	11	221	21	1
[illegible]	157.0	[illegible]	2222222	210	21111	21	1	211	21	111	22211	111	221	211	22111	1111111	111111111	1	111	1	1	1111	11	11	111	1112211	111121111	11	222	21	1
[illegible]	162.6	[illegible]	2211111	211	11111	21	1	221	22	111	11111	222	211	111	22111	1111111	111111111	1	111	1	1	1111	11	11	111	1121111	111111121	11	222	21	1
[illegible]	167.4	[illegible]	2211111	211	21111	21	1	211	11	111	22211	111	222	111	21111	1111111	111111111	2	111	1	1	1111	11	11	111	1111112	111111111	11	222	21	1
[illegible]	172.4	[illegible]	2211111	211	22111	11	1	222	11	111	22111	222	111	111	22111	1111111	111111111	1	111	1	1	1111	11	11	111	1111112	111111211	11	222	21	1
[illegible]	177.4	[illegible]	2111111	211	11111	21	1	211	21	111	22221	111	222	111	21111	1111111	111111111	1	111	1	1	1111	11	11	111	1121111	111121111	11	222	21	1
[illegible]	182.4	[illegible]	2222111	211	22221	22	1	221	21	111	22111	111	221	111	21111	1111111	111111111	1	111	1	1	1111	11	11	111	1121111	111111121	11	221	21	1
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[illegible]	191.9	[illegible]	2221111	211	22222	11	1	221	10	111	21111	211	211	111	21111	1111111	111111111	1	111	1	1	1111	11	11	111	1211211	111111112	11	222	21	1
[illegible]	194.0	[illegible]	2111111	211	21111	11	1	111	11	111	21111	111	211	111	22111	1111111	111111111	2	112	1	1	1111	11	11	111	1112111	112111111	11	221	21	1
[illegible]	198.1	[illegible]	2111111	211	21111	11	1	211	11	111	21111	111	211	111	22111	1111111	111111111	1	111	1	1	1111	11	11	111	1112111	111111211	11	221	21	1
[illegible]	201.3	[illegible]	2221111	211	22211	21	1	222	21	000	00000	000	000	000	21111	1111111	111111111	1	111	1	1	1111	11	11	111	1221111	111121111	11	222	12	1
[illegible]	206.9	[illegible]	2221111	211	22211	11	1	222	21	111	21111	111	221	111	21111	1111111	111111111	1	111	1	1	1111	11	11	111	1121111	111111121	11	222	21	1
[illegible]	209.0	[illegible]	2111111	211	21111	11	1	211	11	111	11111	111	111	111	22111	1111111	111111111	2	121	1	1	1111	11	11	111	1112111	111111111	11	221	12	1
[illegible]	213.1	[illegible]	2111111	211	22211	11	1	211	21	111	11111	211	221	111	21111	1111111	111111111	1	111	1	1	1111	11	11	111	1121111	111111111	11	221	21	1
[illegible]	219.4	[illegible]	2211111	211	22111	11	1	211	11	111	21111	211	111	111	22111	1111111	111111111	1	111	1	1	1111	11	11	111	1121111	111111211	11	211	21	1
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[illegible]	230.0	[illegible]	2111111	211	22111	21	1	111	11	111	11111	111	211	111	21111	1111111	111111111	1	111	1	1	1111	11	11	111	1121111	111111112	11	221	12	1
[illegible]	233.3	[illegible]	2211111	211	22111	11	1	111	11	111	21111	111	111	111	22111	1111111	111111111	1	111	1	1	1111	11	11	111	1121111	111211111	11	221	12	1
[illegible]	240.9	[illegible]	2222211	211	22111	21	1	211	21	111	21111	111	221	111	22111	1111111	111111111	1	111	1	1	1111	11	11	111	1221111	111211111	11	222	21	1
[illegible]	245.9	[illegible]	2111111	211	22111	11	1	111	11	111	21111	111	111	111	22111	1111111	111111111	1	111	1	1	1111	11	11	111	1112111	111111211	11	221	21	1
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[illegible]	262.1	[illegible]	2222222	211	00000	00	0	000	00	000	00000	000	000	000	00000	0000000	000000000	1	111	1	1	1111	11	11	111	1121111	111211111	22	211	21	1
[illegible]	265.1	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	11111	1111111	111111111	1	111	1	1	1111	11	11	111	1111112	111211111	11	221	12	1
[illegible]	269.2	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	11111	2222211	111111111	1	111	1	1	1111	11	11	111	1121111	112111111	22	221	22	1
[illegible]	275.8	[illegible]	2222222	211	00000	00	0	000	00	000	00000	000	000	000	00000	0000000	000000000	1	111	1	1	1111	11	11	111	1121111	112111111	11	211	21	1
[illegible]	281.7	[illegible]	2111111	222	00000	00	0	000	00	000	00000	000	000	000	00000	0000000	000000000	1	111	1	1	1111	11	11	111	1111112	121111111	22	211	21	1
[illegible]	285.5	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	11111	1111111	111111111	2	211	1	1	1111	11	11	111	1112111	111211111	11	000	00	1
[illegible]	288.2	[illegible]	2111111	211	22111	21	1	111	11	111	11111	111	211	111	21111	1111111	111111111	1	111	1	1	1111	11	11	111	1112111	111111121	11	211	12	1
[illegible]	290.5	[illegible]	2111111	211	22111	22	1	211	11	111	21111	211	211	111	21111	1111111	111111111	1	111	1	1	1111	11	11	111	1121111	121111111	11	211	12	1
[illegible]	291.5	[illegible]	2221111	211	21111	22	1	111	21	221	11111	221	221	111	21111	1111111	111111111	1	111	1	1	1111	11	11	111	1111112	112111111	11	221	21	1
[illegible]	294.1	[illegible]	2111111	211	22111	11	1	111	11	111	11111	111	111	111	21111	1111111	111111111	2	112	1	1	1111	11	11	111	1112111	111111211	11	221	12	1
[illegible]	295.5	[illegible]	2211111	221	21111	11	1	111	11	111	11111	111	111	111	21111	1111111	111111111	2	121	1	1	1111	11	11	111	1112111	111111211	11	221	12	1
[illegible]	297.4	[illegible]	2111111	222	22111	11	1	111	11	211	11111	221	211	111	21111	1111111	111111111	1	111	1	1	1111	11	11	111	1121111	112111111	11	211	12	1
[illegible]	302.5	[illegible]	2111111	211	22111	11	1	111	11	111	11111	211	211	111	22211	1111111	111111111	1	111	1	1	1111	11	11	111	1121111	112111111	11	221	11	1
[illegible]	307.0	[illegible]	2221111	211	22222	11	1	211	21	221	21111	111	211	111	21111	1111111	111111111	1	111	1	1	1111	11	11	111	1121111	112111111	11	221	21	1
[illegible]	309.9	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	11111	1111111	111111111	1	111	1	1	1111	11	11	111	1112111	111211111	11	221	12	1
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[illegible]	314.5	[illegible]	2211111	211	22111	11	1	111	11	111	11111	111	111	111	21111	1111111	111111111	2	121	1	1	1111	11	11	111	1112111	112111211	11	221	12	1
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[illegible]	327.5	[illegible]	2222222	211	22222	21	1	111	11	111	11111	111	111	111	11111	1111111	111111111	1	111	1	1	1111	21	11	111	1111211	112111121	11	221	21	1
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SAMPLE NUMBER	DEPTH	GRAIN SIZE 1 2 3 4 5 6 7 8 9 10 11	% MATRIX	% CEM	BK	% CHERT G	B	GN	WH	BK	% QUARTZITE G	B	WH	% PYR	% ROCK FRAGS	% CLASTIC CARBNT	% CARBONACOUS MATERIAL	A M	L SCL OF LAM	L	D	SCL ORD BEDS	CT BG	CP HO	FT ASC	COLOR FRESH BD L DG RGGGBDD	COLOR WEATHERING BD L DLGRY RGGDDBBDDD	CA SV	FRD S MAR	SI PK	Y R
[illegible]	345.8	1112222222111111111111	2222111	211	22221	21	1	111	11	111	21111	111	211	111	11111	1111111	111111111	2	121	1	2	1121	11	11	111	1121111	1121111111	11	221	21	1
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SAMPLE NUMBER	DEPTH	GRAIN SIZE 1 2 3 4 5 6 7 8 9 10 11	% MATRIX	% CEM	BK	% CHERT G	B	GN	WH	BK	% QUARTZITE G	B	WH	% PYR	% ROCK FRAGS	% CLASTIC CARBNT	% CARBONACUS MATERIAL	L A M	SCL OF LAM	C L	O B	SCL GRD BEDS	CT BG	CP HO	KT ASC	COLOR FRESH BD L G RGGGBGB	COLOR WEATHERING BD L LGRY RGGGBGBGB	CA SV	RND S AAR	ST PR	P R
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SAMPLE NUMBER	DEPTH	GRAIN SIZE 1 2 3 4 5 6 7 8 9 10 11	% MATRIX	% CEM	% CHERT DK	G	B	GN	WH	BK	% QUARTZITE G	B	WH	% PYR	% ROCK FRAGS	% CLASTIC CARBNT	CARBONACEOUS MATERIAL	L A M	SCL CP LAM	C L	G B	SCLL ORD BEDS	CI BO	CP NO	RT ASC	COLOR FRESH	COLOR WEATHERING	CA SV	RND ARR	ST PR	P R
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SAMPLE NUMBER	DEPTH	GRAIN SIZE 1 2 3 4 5 6 7 8 9 10 11	% MATRIX	% CEM	% CHERT BK	G	D	GN	WH	% QUARTZITE BK	G	D	WH	% PYR	% ROCK FRAGS	% CLASTIC CARBNT	% CARBNACOUS MATERIAL	LAM	SCE OF LAM	C L	O D	SCLE GRD BEDS	CT BG	CP NO	RT ASC	COLOR FRESH	COLOR WEATHERING	CA	HRD S	ST	P R
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SAMPLE NUMBER	DEPTH	GRAIN SIZE 1 2 3 4 5 6 7 8 9 10 11	% MATRIX	% CEM	BK	% CHERT G	B	GN	WH	BK	% QUARTZITE G	B	WH	% PYR	% ROCK FRAGS	% CLASTIC CARBNT	% CARBNACEOUS MATERIAL	L A M	SCL OF LAM	C L	G B	SCL GRD BEDS	CT BG	CP HO	RT ASC	COLOR FRESH	COLOR WEATHERING	CA 3/	MIN ARR	ST P	P R
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SAMPLE NUMBER	DEPTH	GRAIN SIZE 1 2 3 4 5 6 7 8 9 10 11	% MATRIX	% CEM	BK	% CHERT G	D	GN	WH	BK	% QUARTZITE G	D	WH	% PYR	% ROCK FRAGS	% CLASTIC CARBNT	% CARBONACEOUS MATERIAL	L A M	SCC OF LAM	C L	G D	SCLL GRD BEDS	CT BG	CP HU	RT ASC	COLOR FRESH	COLOR WEATHERING	CA ST	S		
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SAMPLE NUMBER	DEPTH	GRAIN SIZE 1 2 3 4 5 6 7 8 9 10 11	% MATRIX	% CEM	BK	% CHERT G	B	GN	WH	BK	% QUARTZITE G	B	WH	% PYR	% ROCK FRAGS	% CLASTIC CARBNT	% CARBNACUS MATERIAL	LAM	SCE OF LAM	C	D	SCLE GRD BEDS	CT BG	CP HO	RT ASC	COLOR FRESH	COLOR WEATHERING	CA	[illegible]	[illegible]
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SAMPLE NUMBER	DEPTH	GRAIN SIZE 1 2 3 4 5 6 7 8 9 10 11	% MATRIX	% CEM	BK	% CHERT G	B	GN	WH	BK	% QUARTZITE G	B	WH	% PYR	% ROCK FRAGS	% CLASTIC CARBNT	% CARBNACEOUS MATERIAL	L A M	SCL OF LAM	C L	U D	SCLL GRD BEDS	CT BG	CP NO	PT ASC	COLOR FRESH BB L GG RGGBBBB	WEATHERING BB L BLGRY RGGBBBBBB	CA SV	ANG S ARR	ST PR	P R
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SAMPLE NUMBER	DEPTH	GRAIN SIZE 1 2 3 4 5 6 7 8 9 10 11	% MATRIX	% CEM	BK	% CHERT G	B	GN	WH	BK	% QUARTZITE G	B	WH	% PYR	% ROCK FRAGS	% CLASTIC CARBNT	% CARBNACUS MATERIAL	LAM	SCL OF LAM	C L	G B	SCLE GRD BEDS	CT BG	CP RD	RT ASC	COLOR FRESH	COLOR WEATHERING	CA SV	RXNS AAR	ST	P
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SAMPLE NUMBER	DEPTH	GRAIN SIZE 1 2 3 4 5 6 7 8 9 10 11	% MATRIX	% CEM	BK	% CHERT G	B	GN	WH	BK	% QUARTZITE G	B	WH	% PYR	% ROCK FRAGS	% CLASTIC CARBNT	% CARBNACOUS MATERIAL	L A M	SCL OF LAM	C L	D B	SCL GRD BEDS	CT BG	CP HO	RT ASC	COLOR FRESH BD L DG RGOSBBB	COLOR WEATHERING BD L DG RGOSBBB	CA SV	RND S ANG	ST R
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SAMPLE NUMBER	DEPTH	GRAIN SIZE 1 2 3 4 5 6 7 8 9 0 1 1	% MATRIX	% CEM	% CHERT BR	G	B	GN	WH	BR	% QUARTZITE G	B	WH	% PYR	% ROCK FRAGS	% CLASTIC CARBNT	% CARBNACUS MATERIAL	L A W	SCL OF LAM	C L	G B	SCLE GRD BEDS	CT BG	CP HO	RT ASC	COLOR FRESH	WEATHERING	CA SV	RND S AA	ST P	P R
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SAMPLE NUMBER	DEPTH	GRAIN SIZE 1 2 3 4 5 6 7 8 9 10 11	% MATRIX	% CEM	BK	% CHERT G	B	GN	WH	BK	% QUARTZITE G	B	WH	% PYR	% ROCK FRAGS	% CLASTIC CARBNT	% CARBNACOUS MATERIAL	LAM	SCL OF LAM	C	O	SCLL GRD BEDS	CT BG	CF HO	HT ASC	COLOR FRESH	COLOR WEATHERING	CA SV	MNO S AAR	ST	
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SAMPLE NUMBER	DEPTH	GRAIN SIZE 1 2 3 4 5 6 7 8 9 10 11	% MATRIX	% CEM	BK	% CHERT G	B	GN	WH	BK	% QUARTZITE G	B	WH	% PYR	% ROCK FRAGS	% CLASTIC CARBNT	% CARBNACUS MATERIAL	LAM	SCL OF LAM	C L	G B	SCLE GRD BEDS	CT BG	CP NO	RT ASC	COLOR FRESH BU L DG RGGGBBB	COLOR WEATHERING BU L DLGRY RGGGBBBBBB	CA SV	MND S AAR	ST P	
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SAMPLE NUMBER	DEPTH	GRAIN SIZE 1 2 3 4 5 6 7 8 9 10 11	% MATRIX	% CEM	% CHERT BK	G	B	GN	WH	BK	% QUARTZITE G	B	WH	% PYR	% ROCK FRAGS	% CLASTIC CARBNT	% CARBONACEOUS MATERIAL	L A M	SCL OF LAM	C G	SCL GRD BEDS	CT BG	CP MO	RT ASC	C O L O R FRESH	WEATH	CA
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[illegible]	[illegible]	[illegible]	2111111	211	22211	11	1	111	11	111	11111	111	111	111	21111	2221111	111111111	2	121	1 1	1111	11	11	111	1211111	111111121	21 211
[illegible]	[illegible]	[illegible]	2211111	211	00000	00	0	000	00	000	00000	000	000	000	00000	0000000	000000000	1	111	1 1	1111	11	11	111	1121111	112111111	21 211
[illegible]	[illegible]	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2222211	111111111	1	111	1 1	1111	11	11	000	1121111	111111121	22 221
[illegible]	[illegible]	[illegible]	2111111	211	22211	11	1	111	11	111	11111	111	111	111	21111	2211111	111111111	2	211	1 1	1111	21	11	111	1121111	112111111	21 211
[illegible]	[illegible]	[illegible]	0000000	000	00000	00	0	000	00	000	00000	000	000	000	00000	0000000	000000000	2	121	1 1	1111	11	11	111	1211111	121111111	11
[illegible]	[illegible]	[illegible]	2111111	221	21111	11	1	111	11	111	11111	111	111	111	21111	2221111	111111111	2	121	1 1	1111	21	11	111	1121111	112111111	22 211
[illegible]	[illegible]	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2221111	111111111	2	121	1 1	1111	21	11	111	1121111	111111121	21 211
[illegible]	275.4	[illegible]	0000000	000	00000	00	0	000	00	000	00000	000	000	000	00000	0000000	000000000	2	121	1 1	1111	21	21	111	2111111	211111111	11
[illegible]	[illegible]	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2222111	111111111	2	121	1 1	1111	11	11	111	1121111	112111111	21 211
[illegible]	279.9	[illegible]	0000000	000	00000	00	0	000	00	000	00000	000	000	000	00000	0000000	000000000	2	121	1 1	1111	11	11	111	1121111	112111111	21 211
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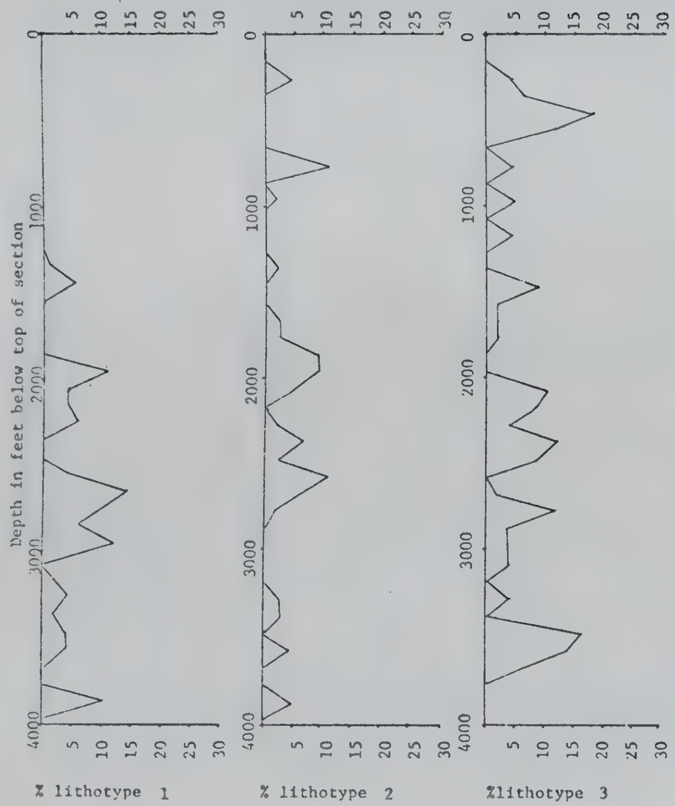
[illegible]	314.4	[illegible]	2111111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2222111	111111111	2	211	1 1	1111	21	11	111	1121111	111111121	22 211
[illegible]	[illegible]	[illegible]	0000000	000	00000	00	0	000	00	000	00000	000	000	000	00000	0000000	000000000	2	121	1 1	1111	11	11	111	1211111	121111111	11

SAMPLE NUMBER	DEPTH	GRAIN SIZE 1 2 3 4 5 6 7 8 9 10 11	% MATRIX	% CEM	BK	% CHERT G	B	GN	WH	BK	% QUARTZITE G	B	WH	% PYR	% ROCK FRAGS	% CLASTIC CARBNT	% CARBONACEOUS MATERIAL									COLOR FRESH	WEATHERED				
[illegible]	[illegible]	111122211111111111111	2111111	211	21111	11	1	111	11	111	11111	111	111	111	21111	2222111	211111111	2	211	1	1	1111	11	21	111	1211111	112111112	21	211	12	1
[illegible]	[illegible]	221111111111111111111	0000000	000	00000	00	0	000	00	000	00000	000	000	000	00000	1111111	222222222	1	111	1	1	1111	11	22	111	2111111	2111111111	11	[illegible]	[illegible]	1

Appendix C - Lithotype Distribution within the Mount Allan, Wind Ridge and Three Sisters Sections

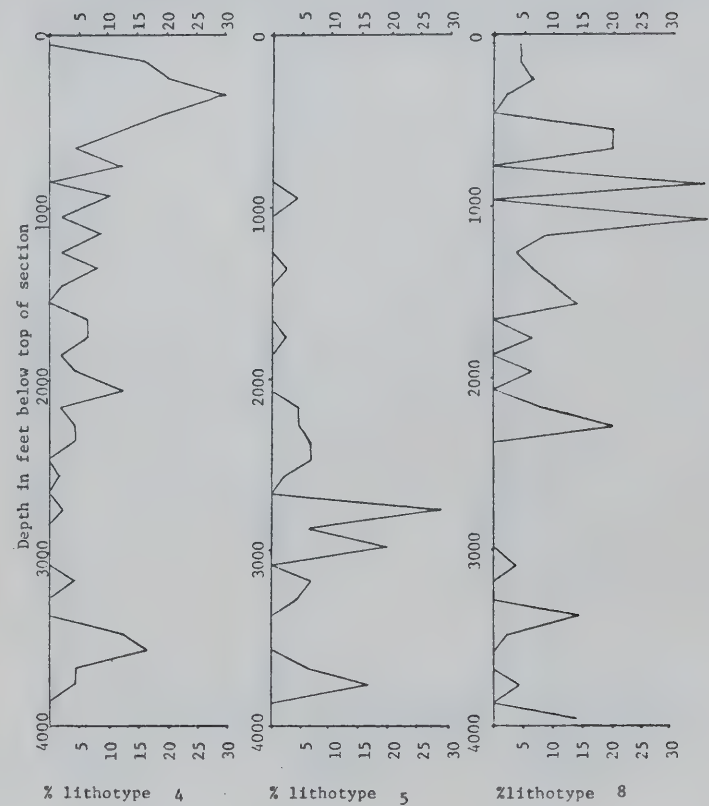
Frequency Distribution of Lithotypes within 100 foot

Intervals for the Mount Allan Section



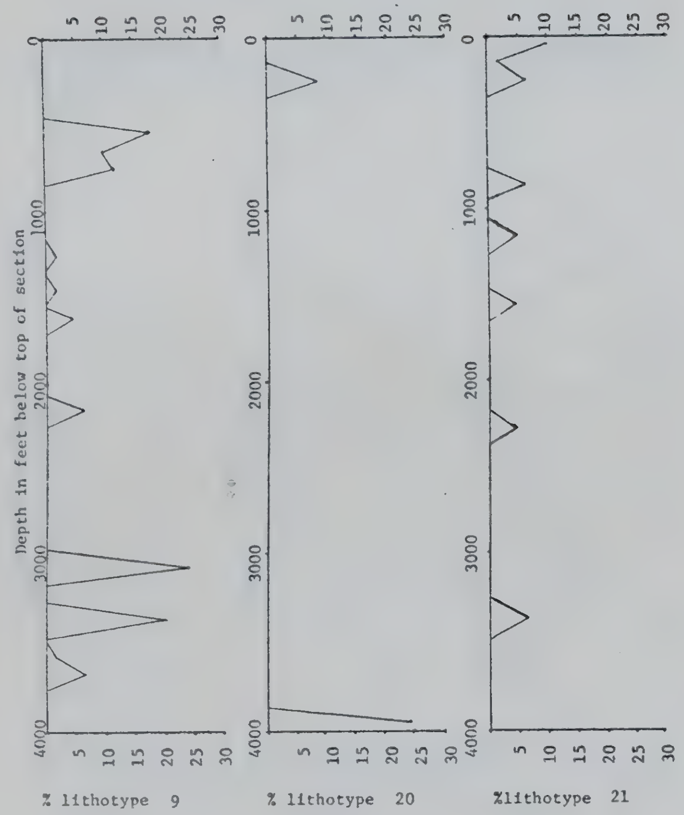
Frequency Distribution of Lithotypes within 100 foot

Intervals for the Mount Allan Section



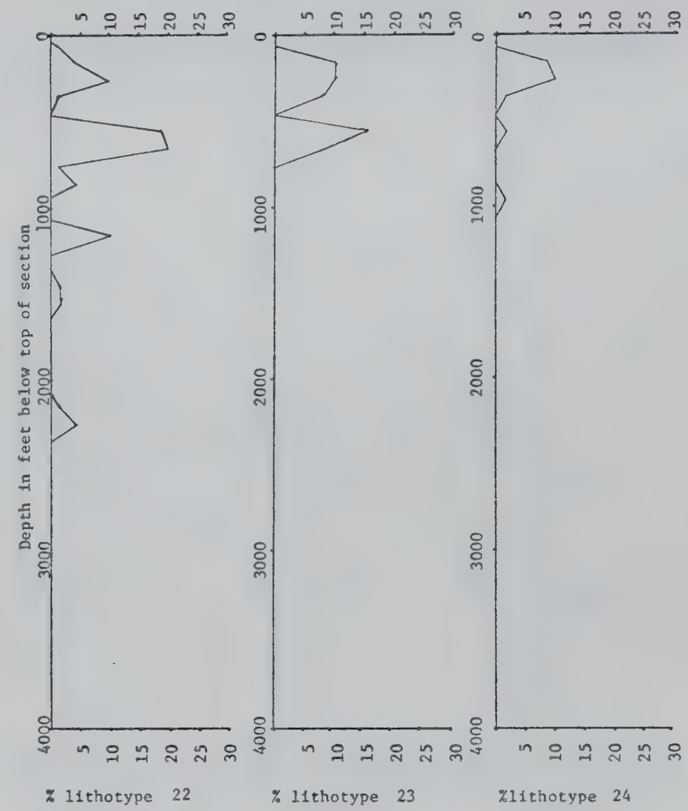
Frequency Distribution of Lithotypes within 100 foot

Intervals for the Mount Allan Section



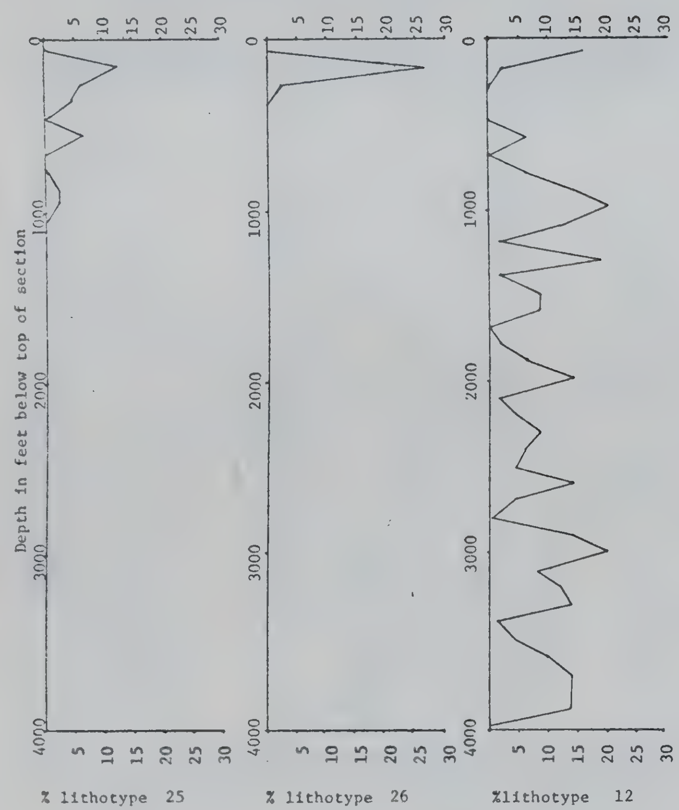
Frequency Distribution of Lithotypes within 100 foot

Intervals for the Mount Allan Section



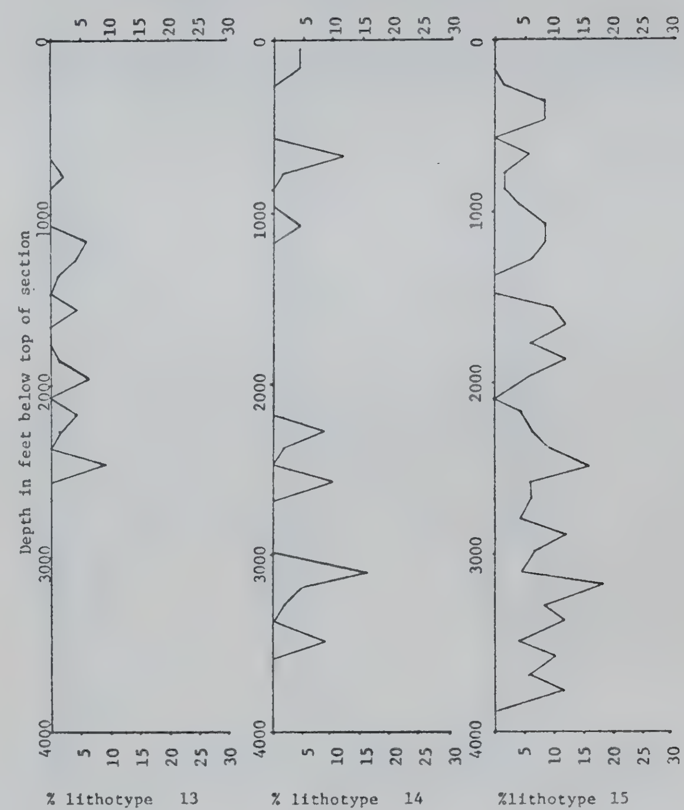
Frequency Distribution of Lithotypes within 100 foot

Intervals for the Mount Allan Section



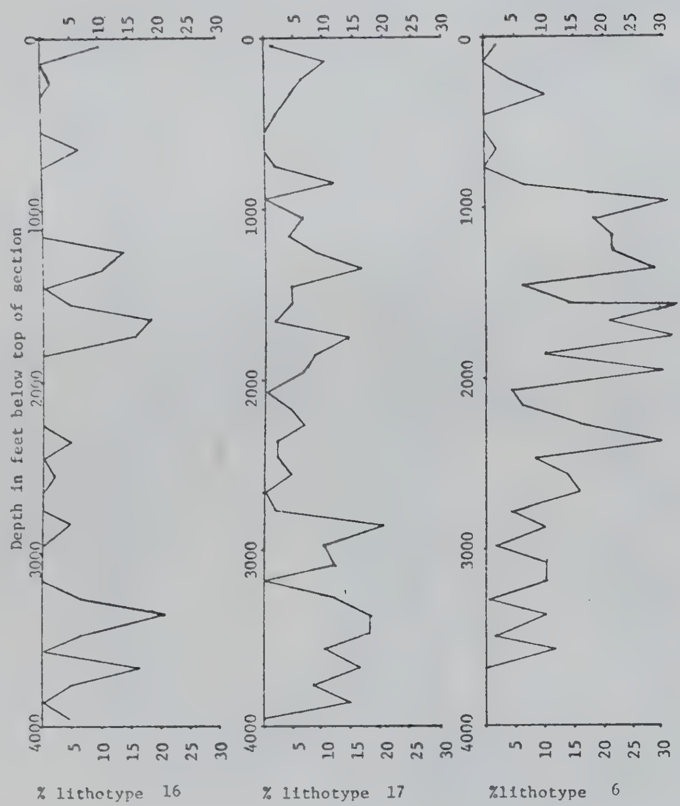
Frequency Distribution of Lithotypes within 100 foot

Intervals for the Mount Allan Section



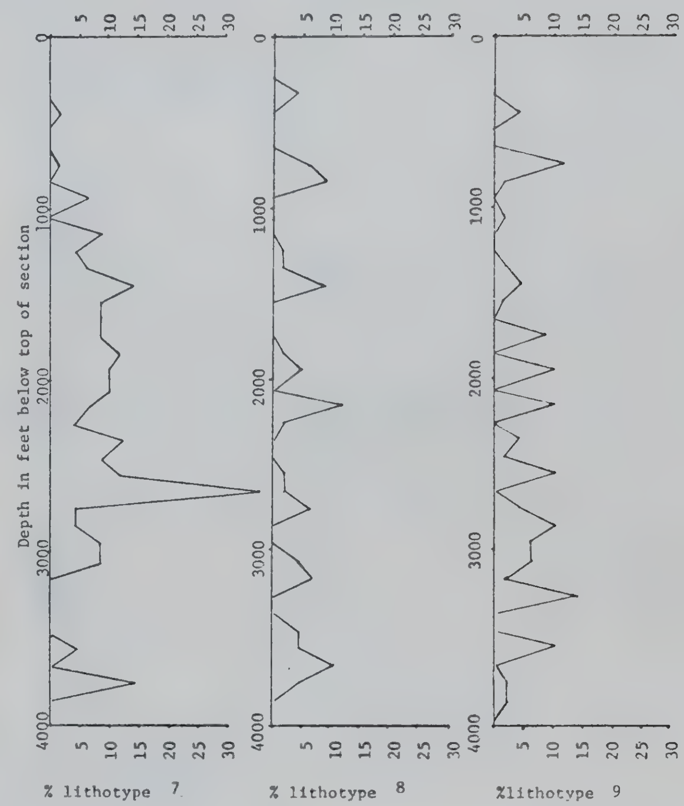
Frequency Distribution of Lithotypes within 100 foot

Intervals for the Mount Allan Section



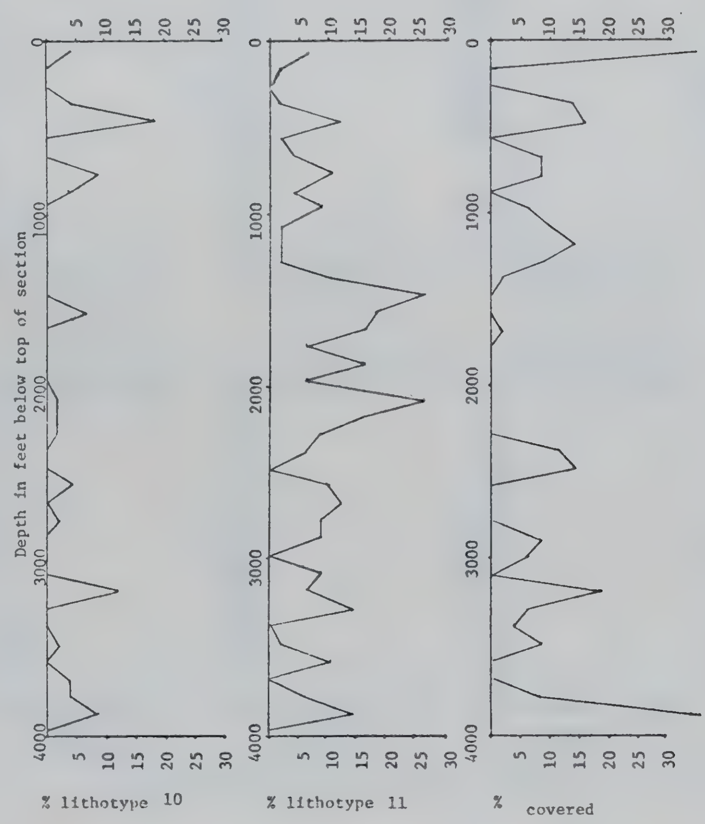
Frequency Distribution of Lithotypes within 100 foot

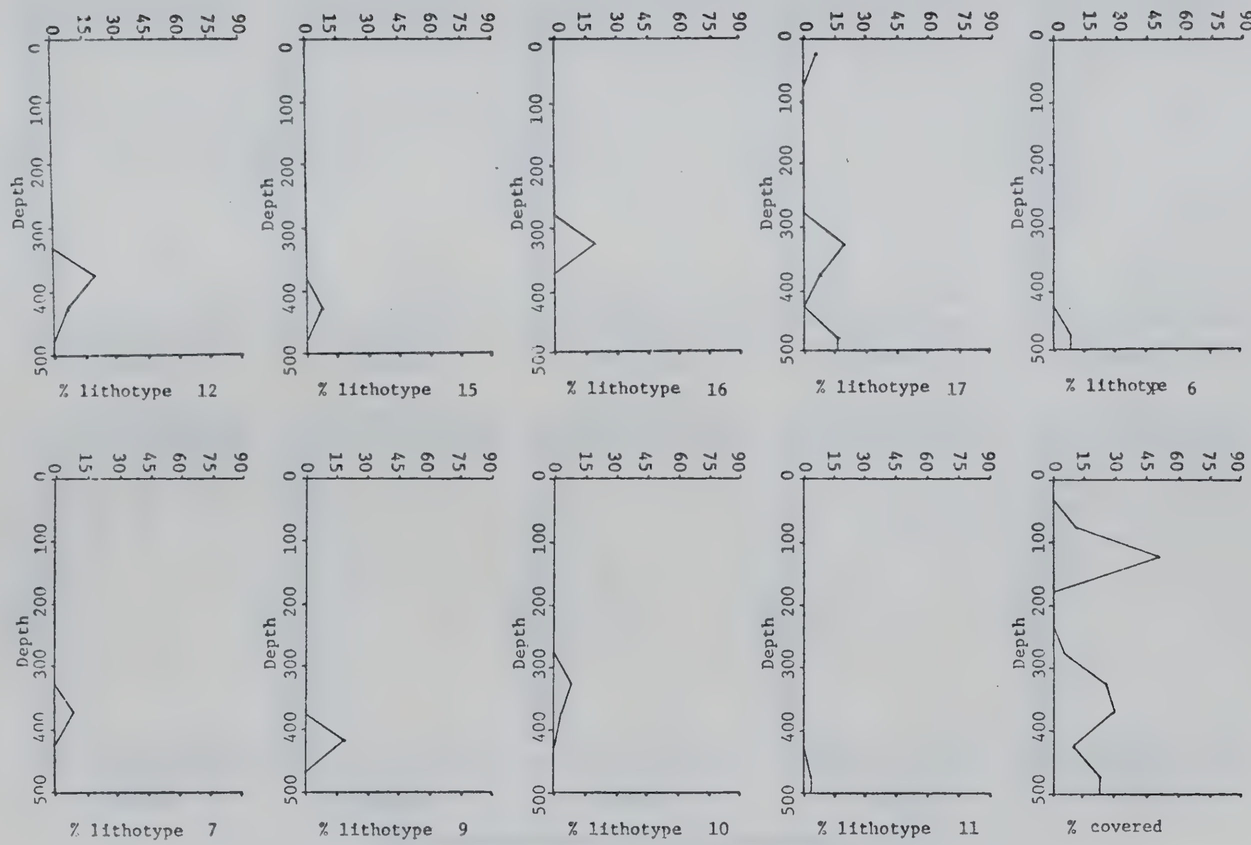
Intervals for the Mount Allan Section



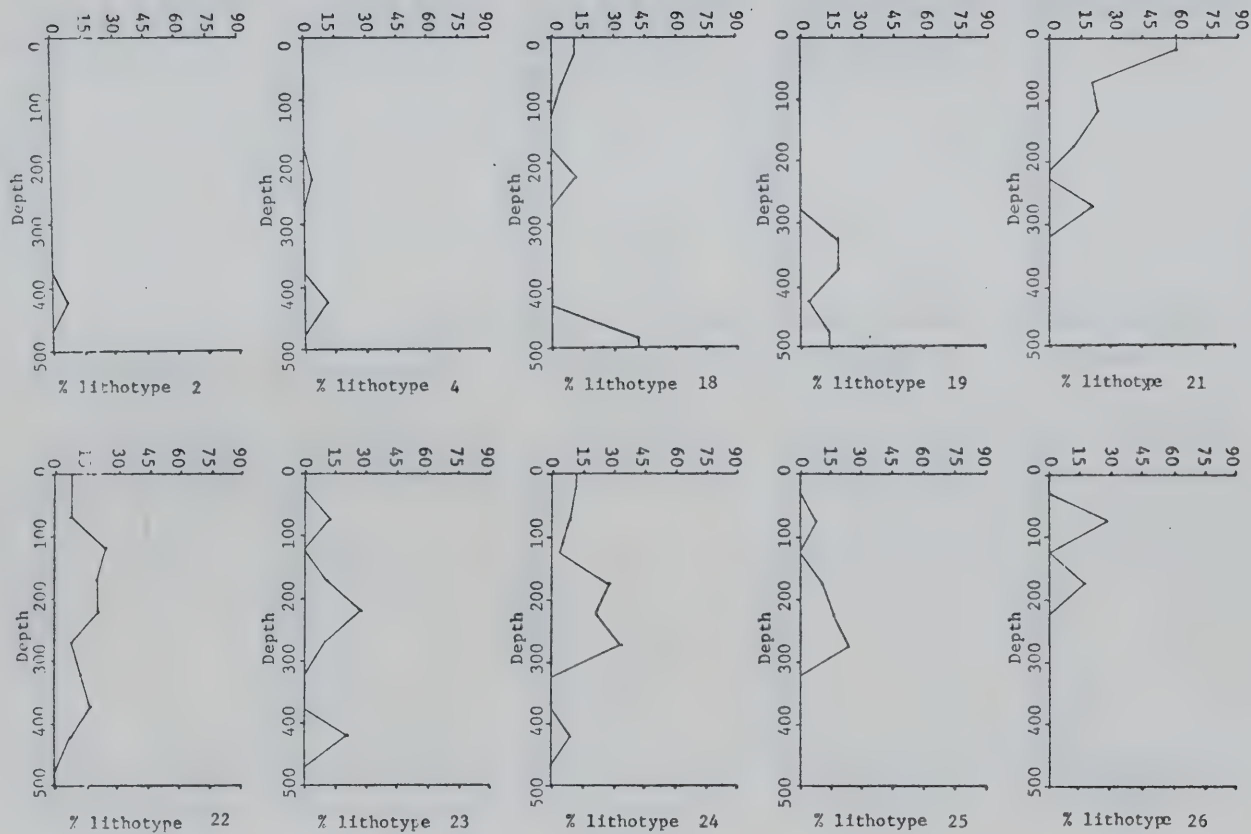
Frequency Distribution of Lithotypes within 100 foot

Intervals for the Mount Allan Section

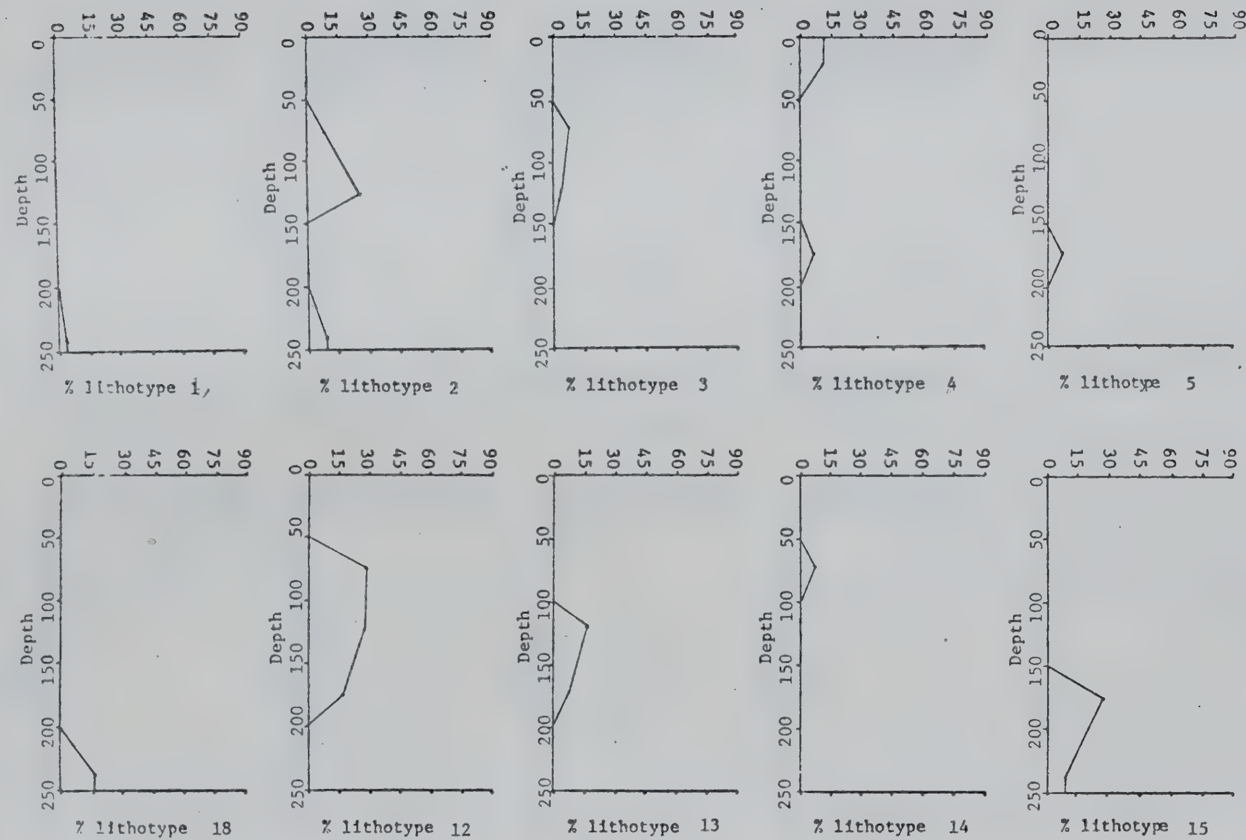




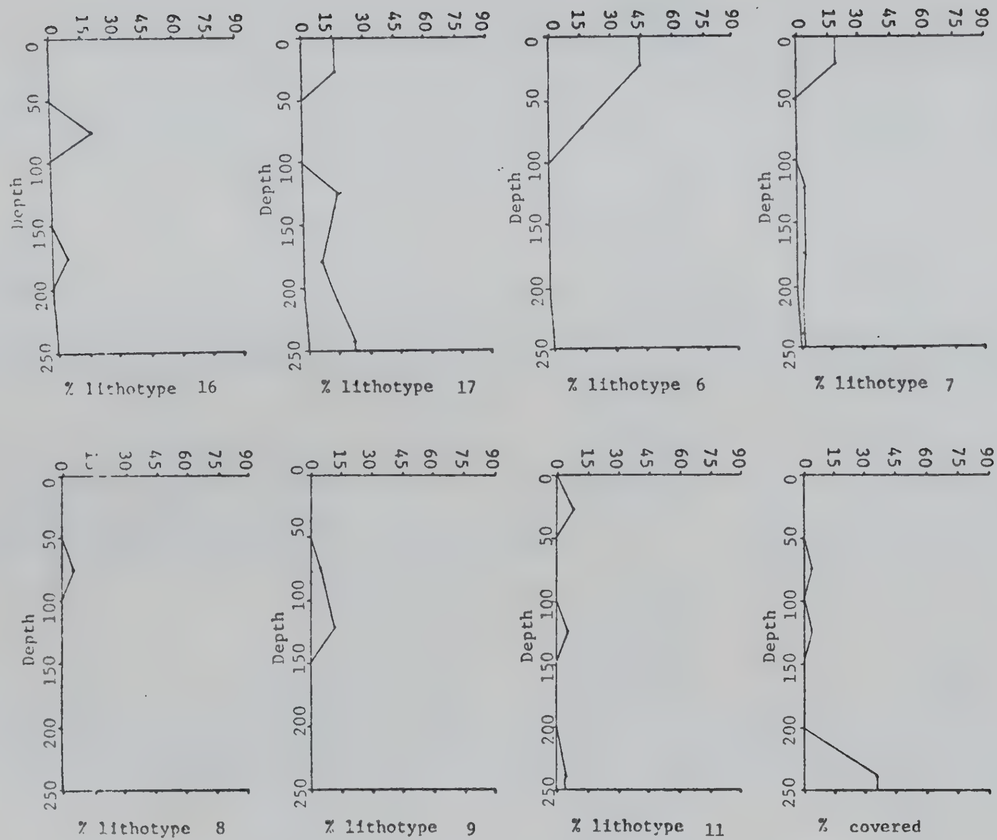
Lithotype distribution within the Wind Ridge section



Lithotype distribution within the Wind Ridge section

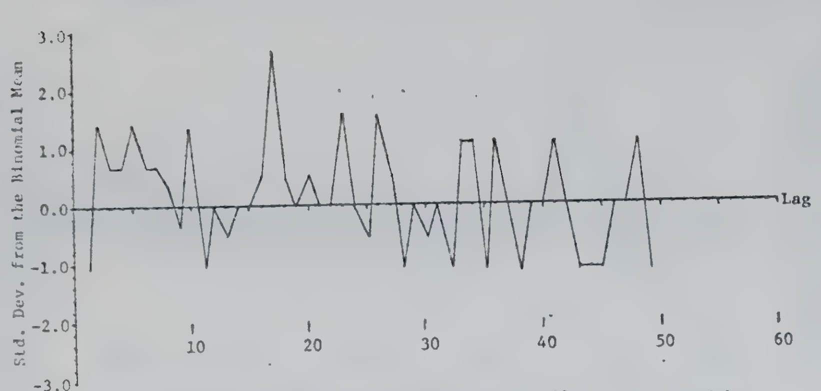


Lithotype distribution within the upper 250 feet of the Three Sisters section

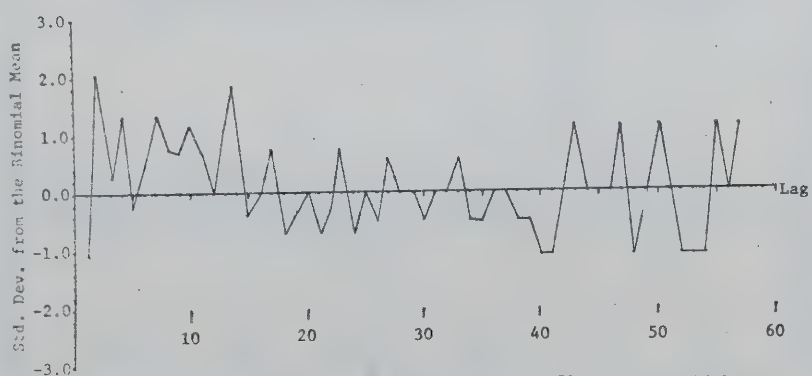


Lithotype distribution within the upper 250 feet of the Three Sisters section

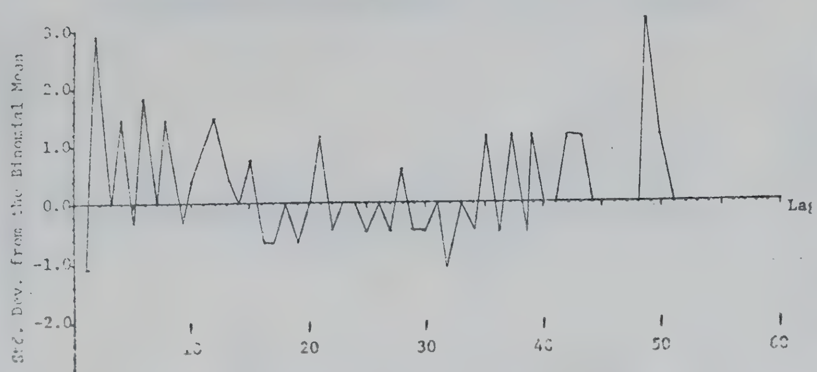
Appendix D - Auto-Association Plots for the Mount Allan Section



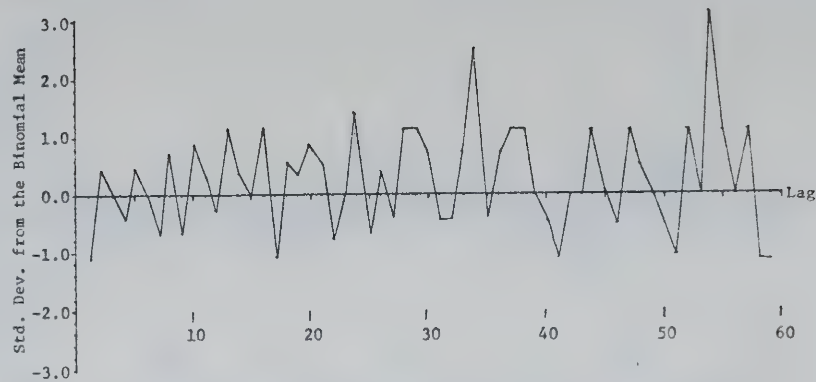
Autoassociation Plot for Interval 0 - 372 for 26 Lithotypes



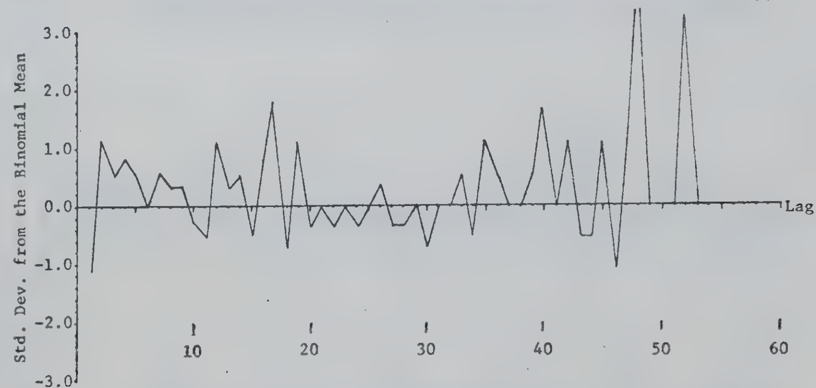
Autoassociation Plot for Interval 372 - 730 for 26 Lithotypes



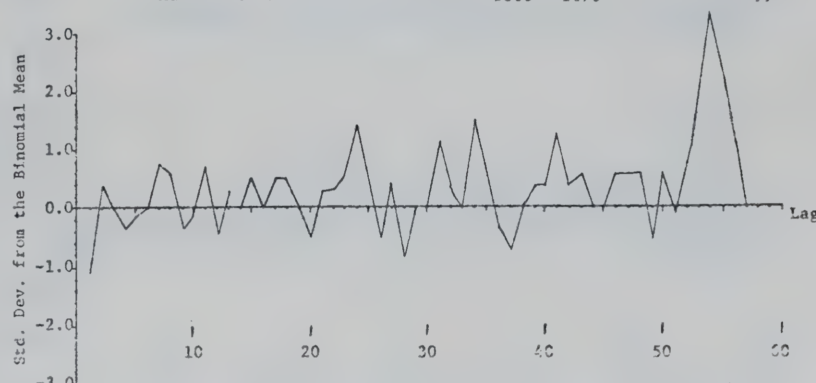
Autoassociation Plot for Interval 730 - 1080 for 26 Lithotypes



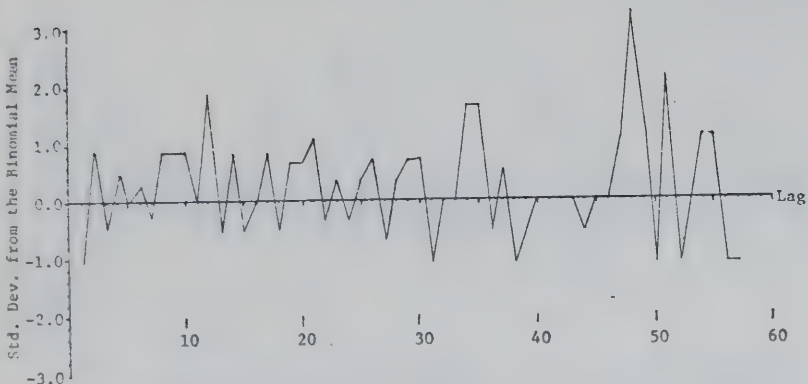
Autoassociation Plot for Interval 1082 - 1366 for 26 Lithotypes



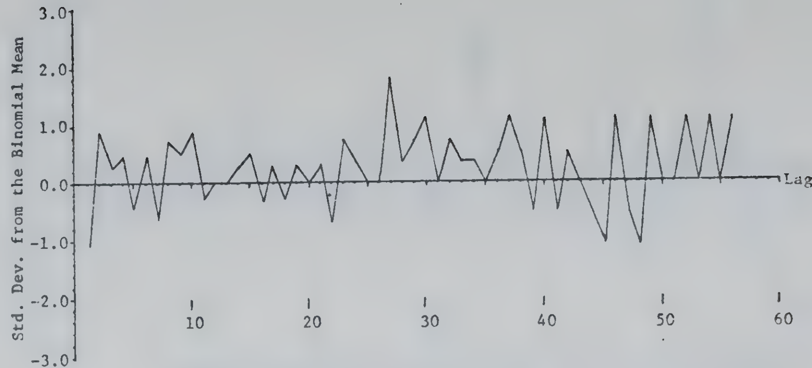
Autoassociation Plot for Interval 1366 - 1670 for 26 Lithotypes



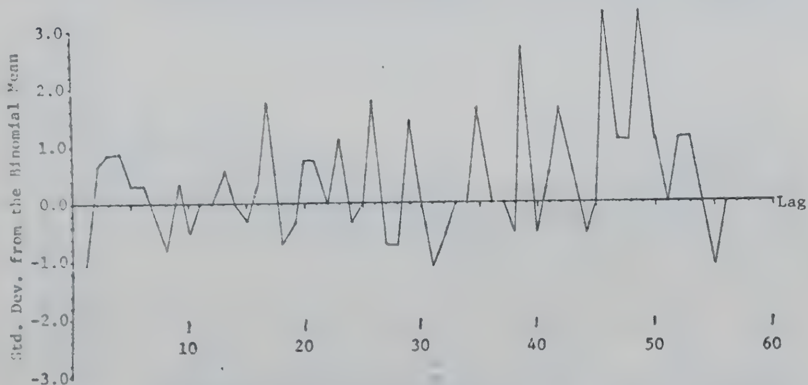
Autoassociation Plot for Interval 1670 -1960 for 26 Lithotypes



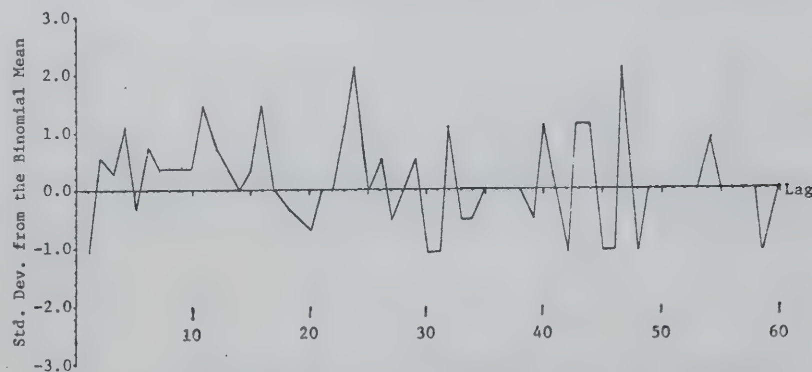
Autoassociation Plot for Interval 1960 - 2222 for 26 Lithotypes



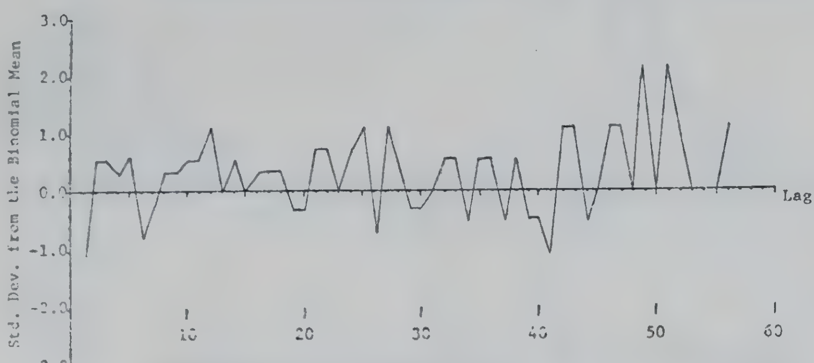
Autoassociation Plot for Interval 2752 - 3040 for 26 Lithotypes



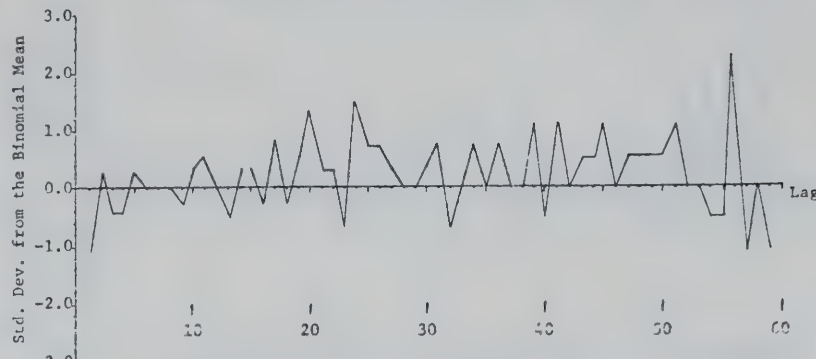
Autoassociation Plot for Interval 2222 - 2476 for 26 Lithotypes



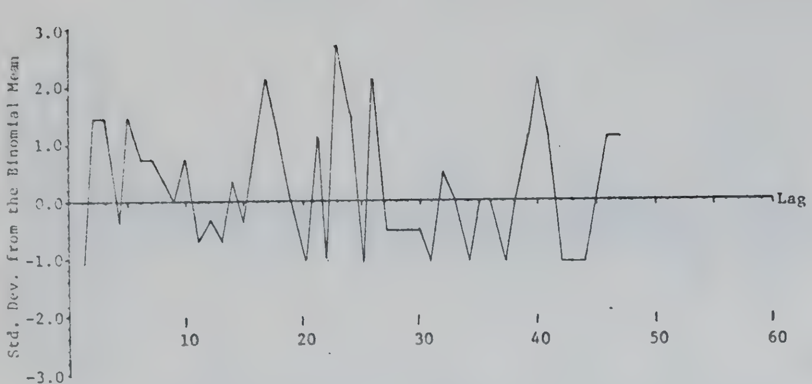
Autoassociation Plot for Interval 3040 - 3398 for 26 Lithotypes



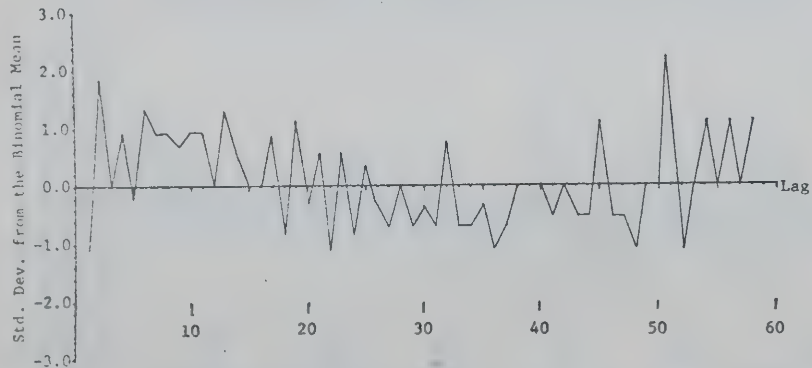
Autoassociation Plot for Interval 2476 - 2752 for 26 Lithotypes



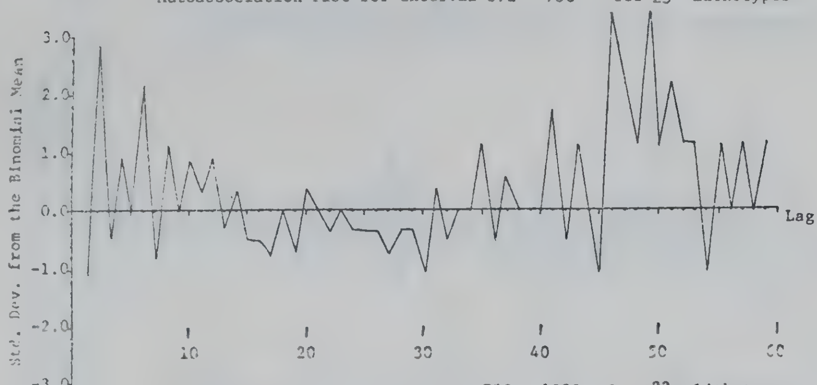
Autoassociation Plot for Interval 3398 - 3864 for 26 Lithotypes



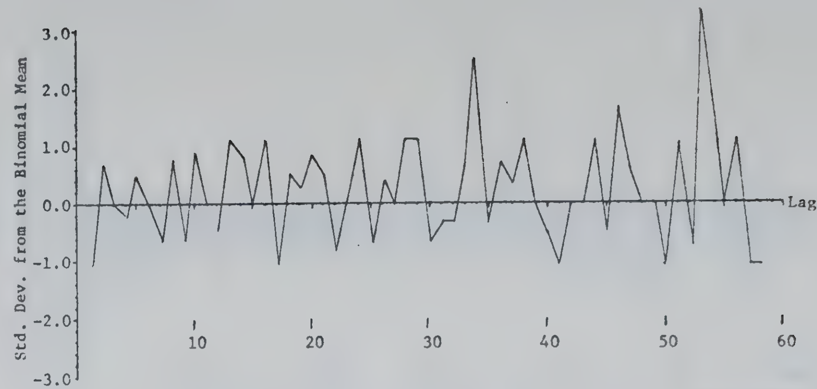
Autoassociation Plot for Interval Ø - 372   for 23 Lithotypes



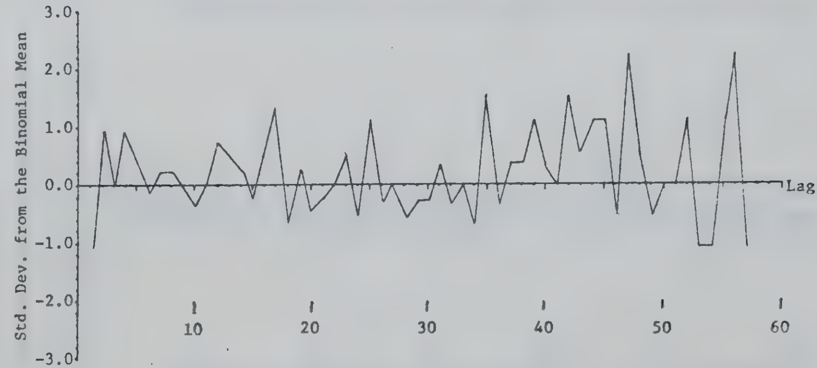
Autoassociation Plot for Interval 372 - 730   for 23 Lithotypes



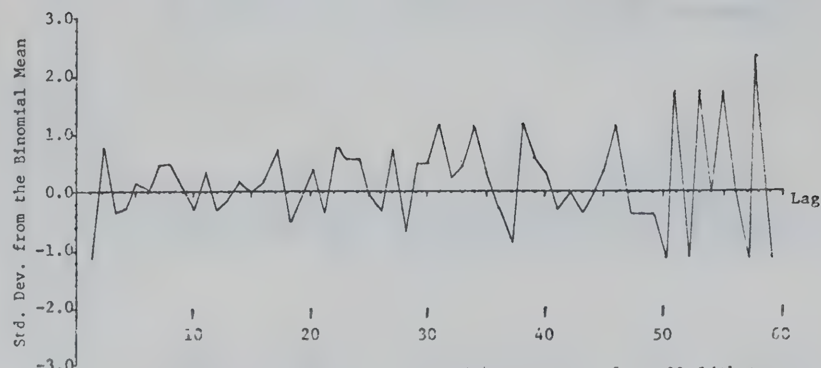
Autoassociation Plot for Interval 730 - 1080 for 23 Lithotypes



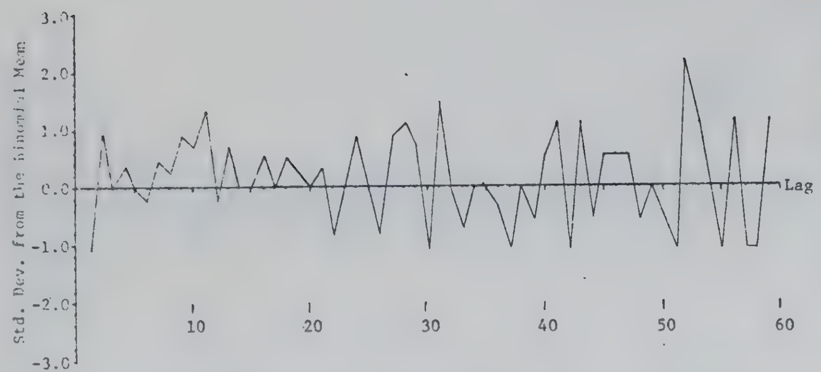
Autoassociation Plot for Interval 1080 - 1366 for 23 Lithotypes



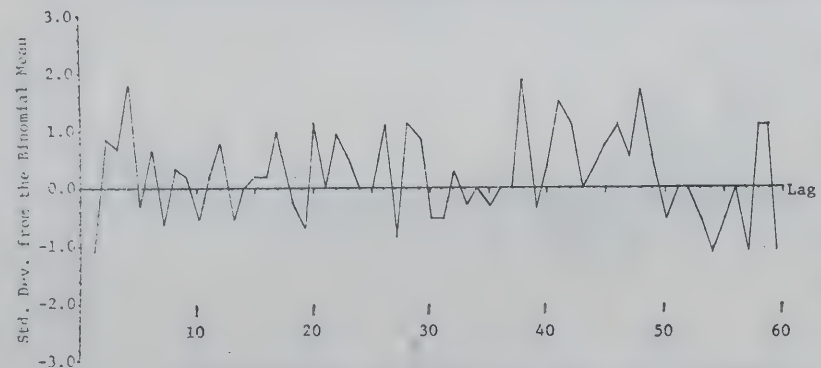
Autoassociation Plot for Interval 1366 - 1670 for 23 Lithotypes



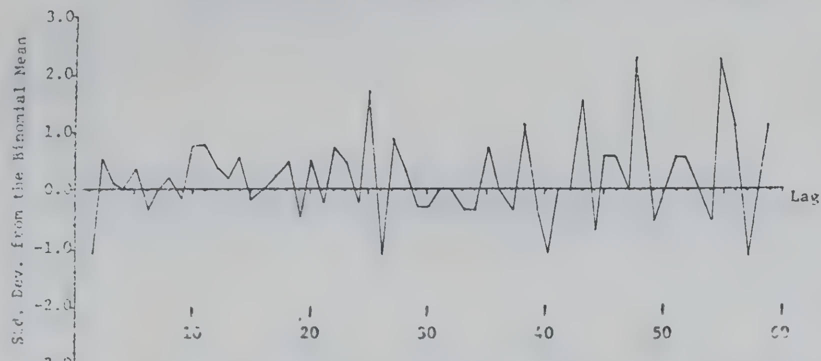
Autoassociation Plot for Interval 1670 - 1960 for 23 Lithotypes



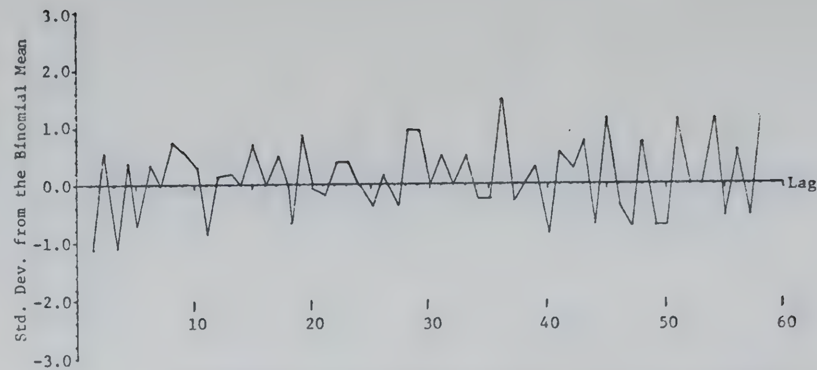
Autoassociation Plot for Interval 1960 - 2222 for 23 Lithotypes



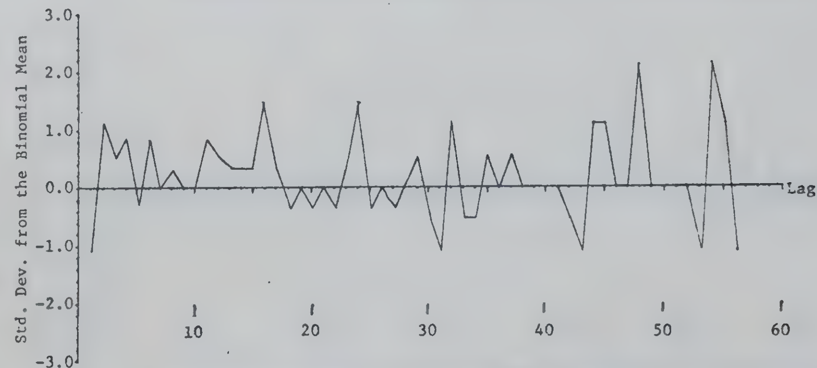
Autoassociation Plot for Interval 2222 - 2476 for 23 Lithotypes



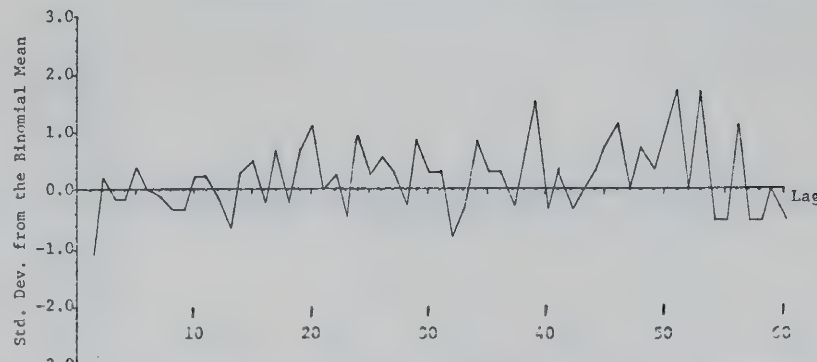
Autoassociation Plot for Interval 2476 - 2752 for 23 Lithotypes



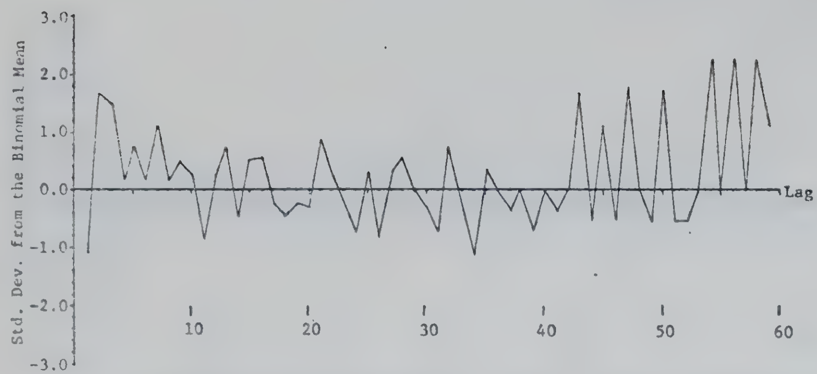
Autoassociation Plot for Interval 2752 - 3040 for 23 Lithotypes



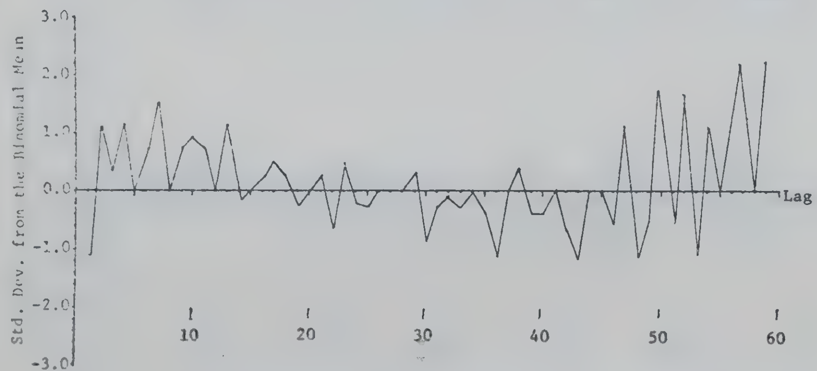
Autoassociation Plot for Interval 3040 - 3398 for 23 Lithotypes



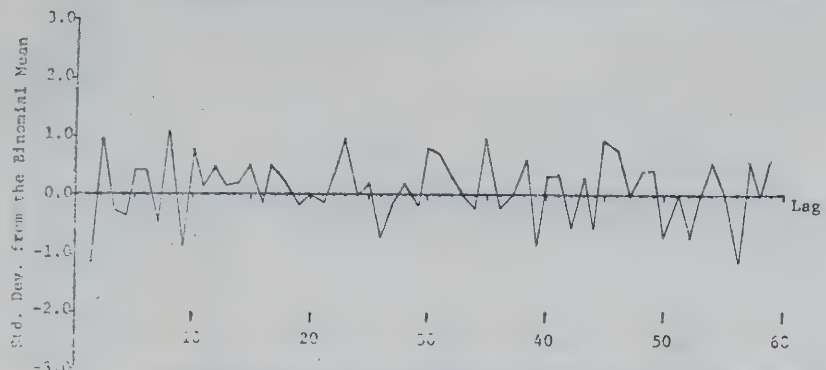
Autoassociation Plot for Interval 3398 - 3864 for 23 Lithotypes



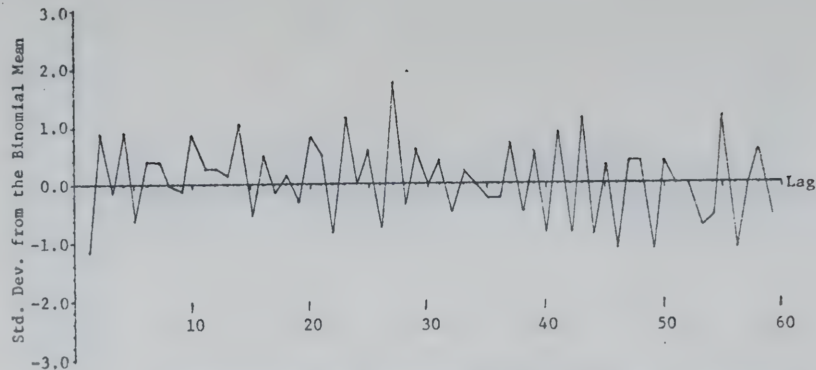
Autoassociation Plot for Interval 0 - 420 for 11 Lithotypes



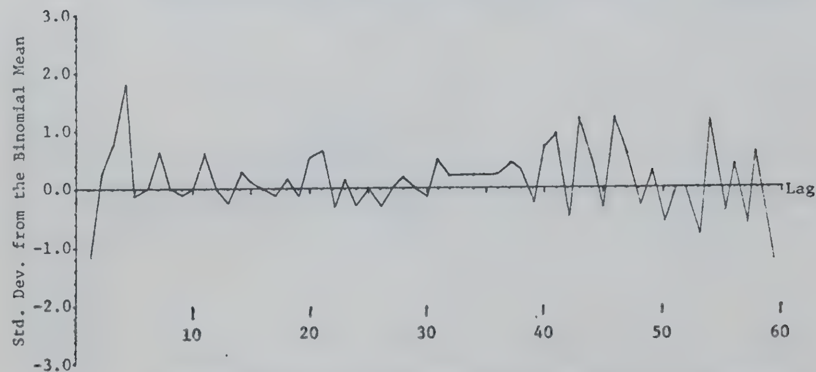
Autoassociation Plot for Interval 420 - 806 for 11 Lithotypes



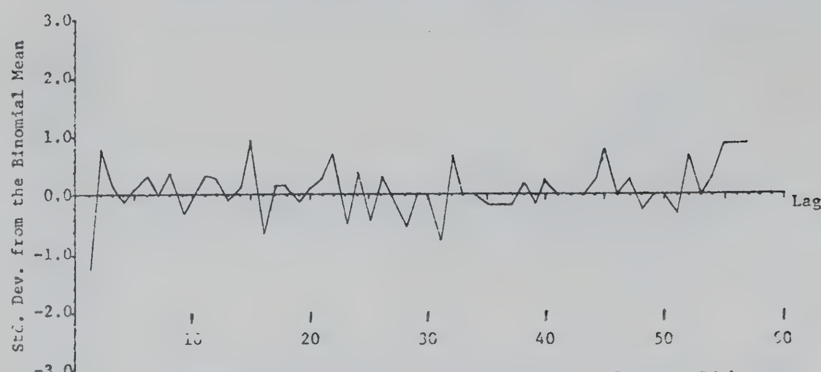
Autoassociation Plot for Interval 806 - 1188 for 11 Lithotypes



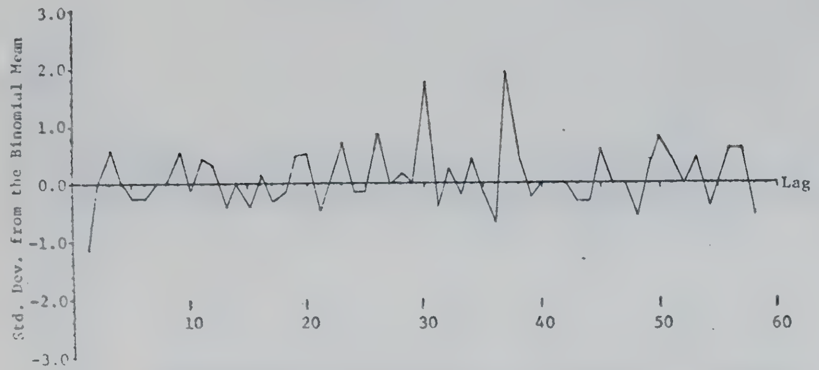
Autoassociation Plot for Interval 1188 - 1482 for 11 Lithotypes



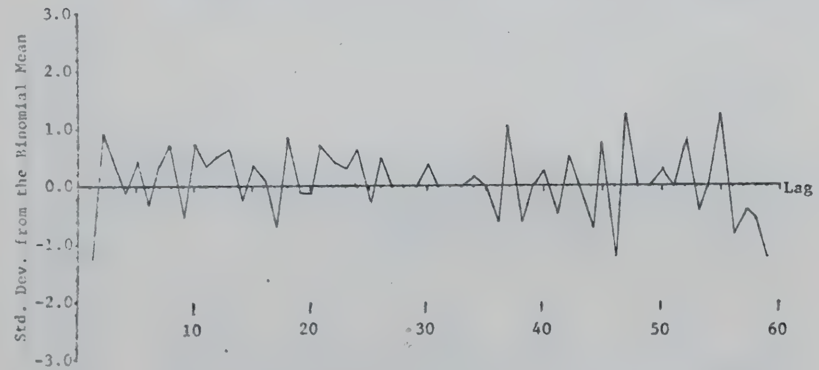
Autoassociation Plot for Interval 1482 - 1830 for 11 Lithotypes



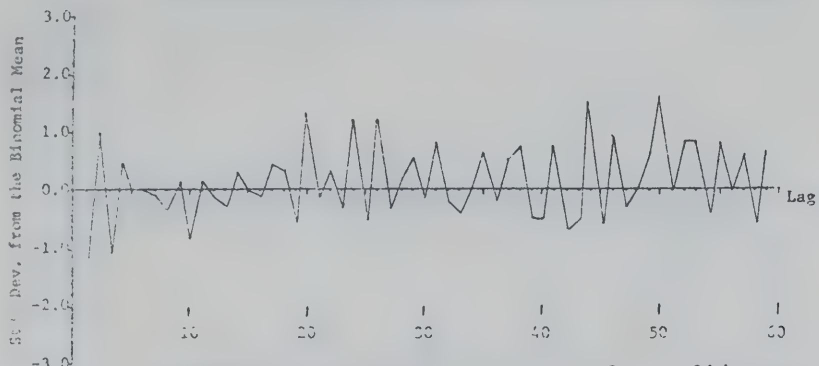
Autoassociation Plot for Interval 1830 - 2134 for 11 Lithotypes



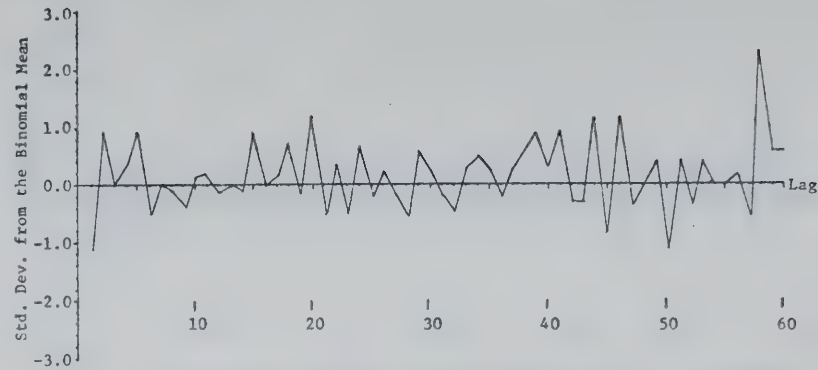
Autoassociation Plot for Interval 2134 - 2430 for 11 Lithotypes



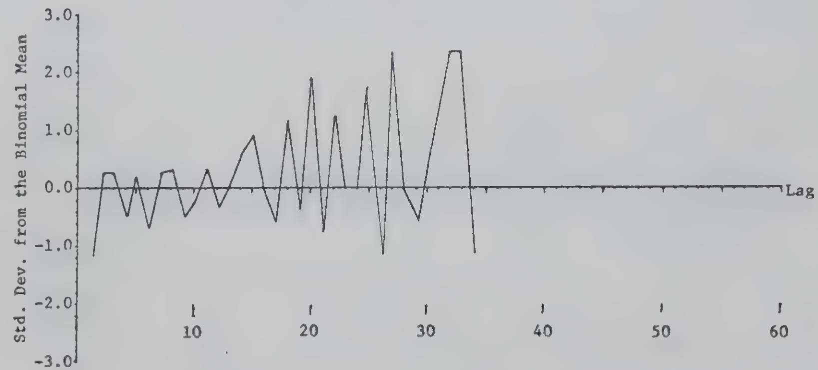
Autoassociation Plot for Interval 2430 - 2762 for 11 Lithotypes



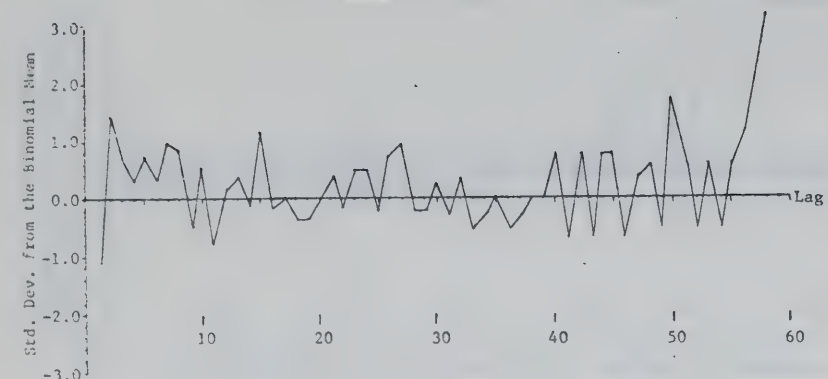
Autoassociation Plot for Interval 2762 - 3168 for 11 Lithotypes



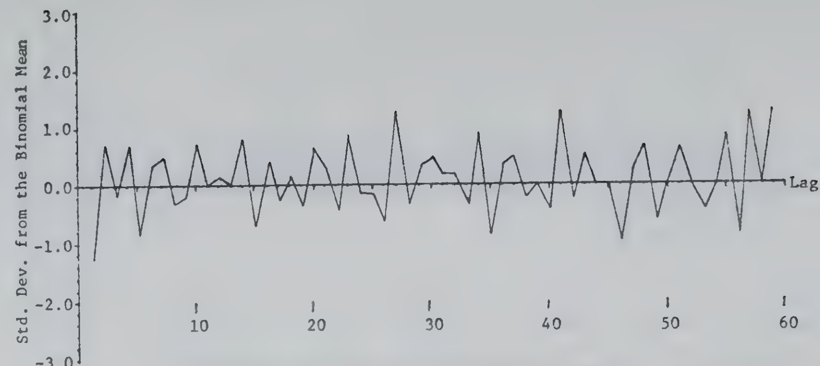
Autoassociation Plot for Interval 3168 - 3562 for 11 Lithotypes



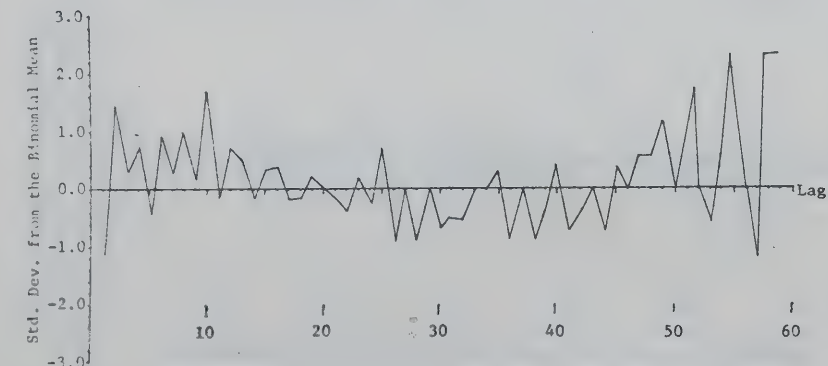
Autoassociation Plot for Interval 3562 - 3864 for 11 Lithotypes



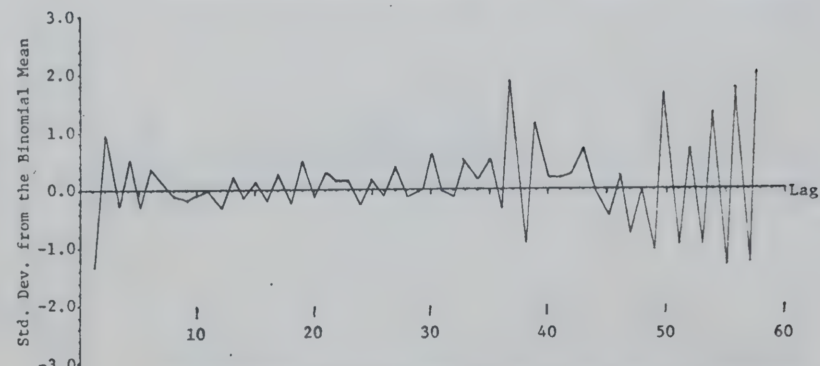
Autoassociation Plot for Interval 0 - 420 for 9 Lithotypes



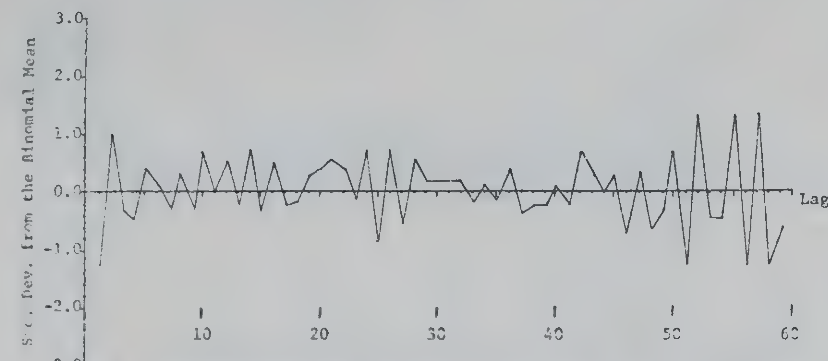
Autoassociation Plot for Interval 1188 - 1482 for 9 Lithotypes



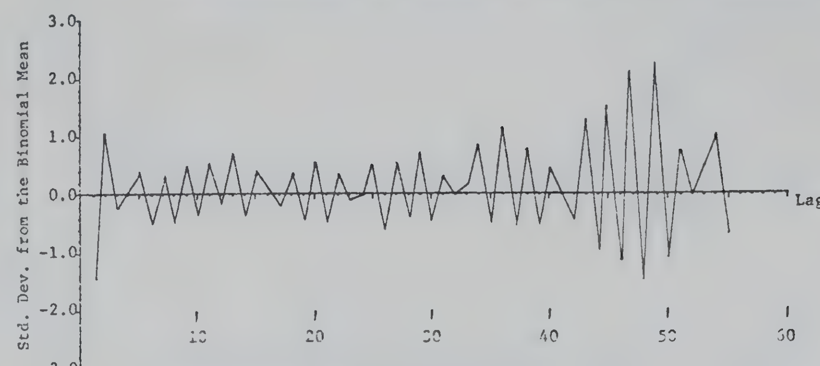
Autoassociation Plot for Interval 420 - 806 for 9 Lithotypes



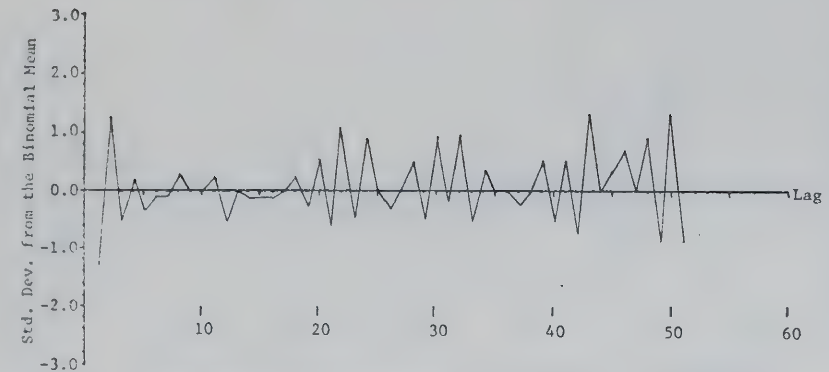
Autoassociation Plot for Interval 1482 - 1830 for 9 Lithotypes



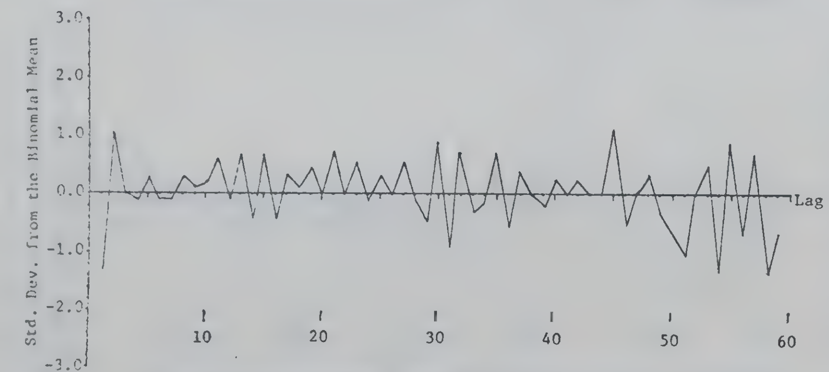
Autoassociation Plot for Interval 806 - 1188 for 9 Lithotypes



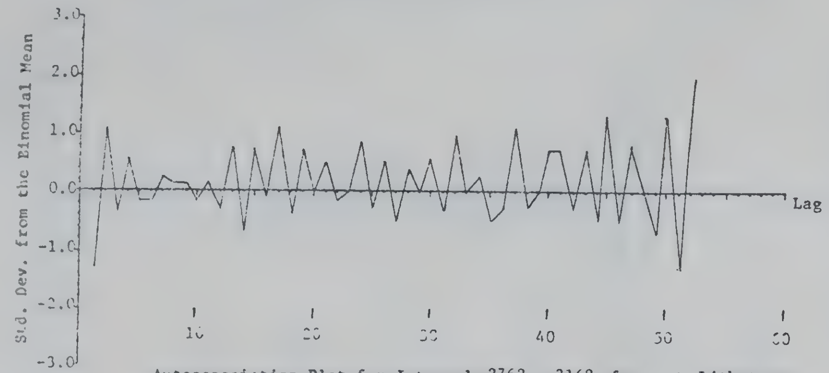
Autoassociation Plot for Interval 1830 - 2134 for 9 Lithotypes



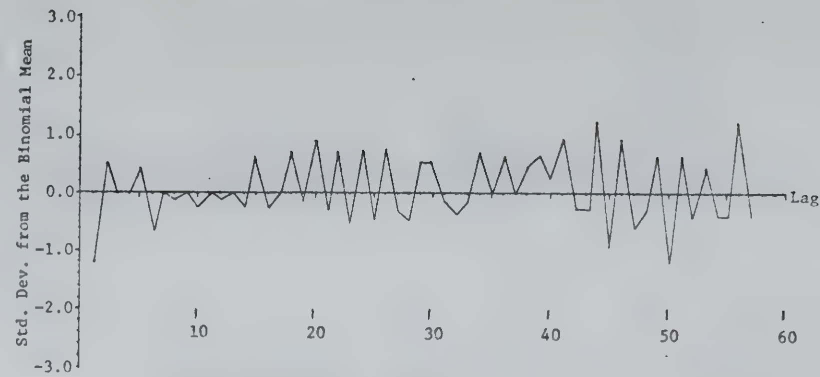
Autoassociation Plot for Interval 2134 - 2430 for 9 Lithotypes



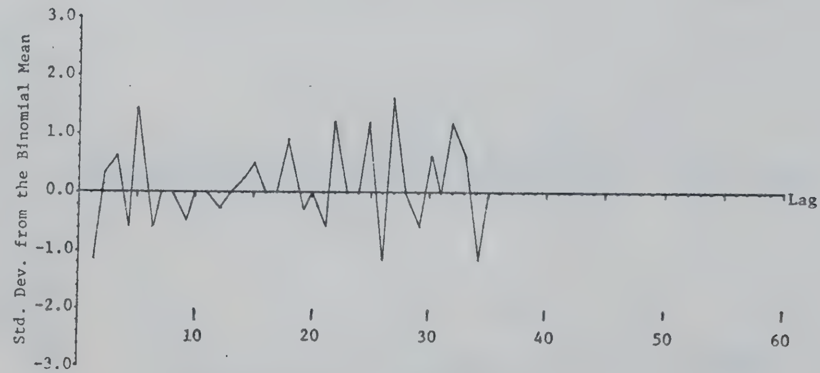
Autoassociation Plot for Interval 2430 - 2762 for 9 Lithotypes



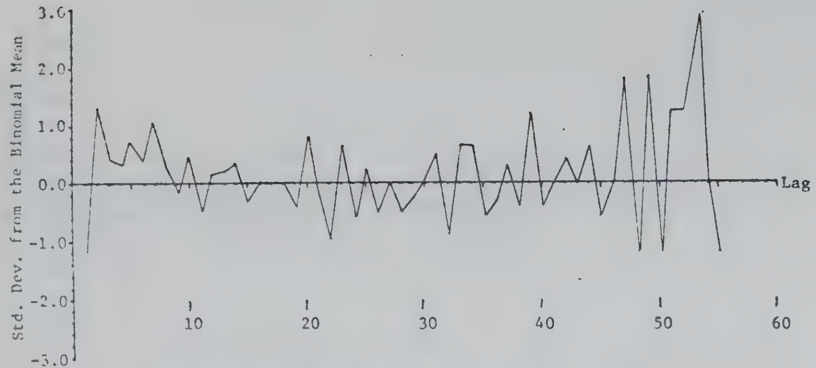
Autoassociation Plot for Interval 2762 - 3168 for 9 Lithotypes



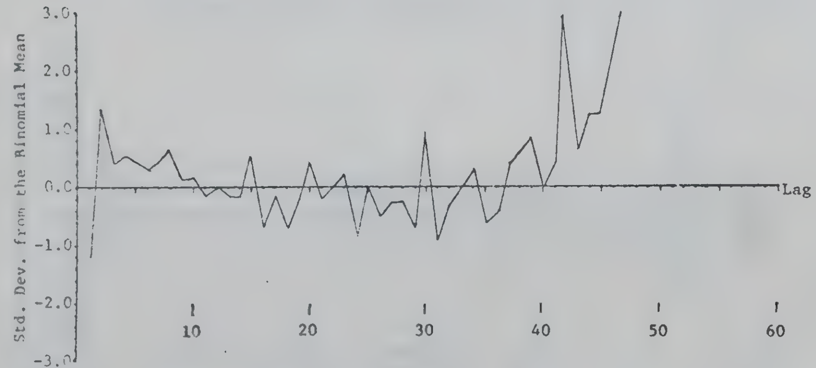
Autoassociation Plot for Interval 3168 - 3562 for 9 Lithotypes



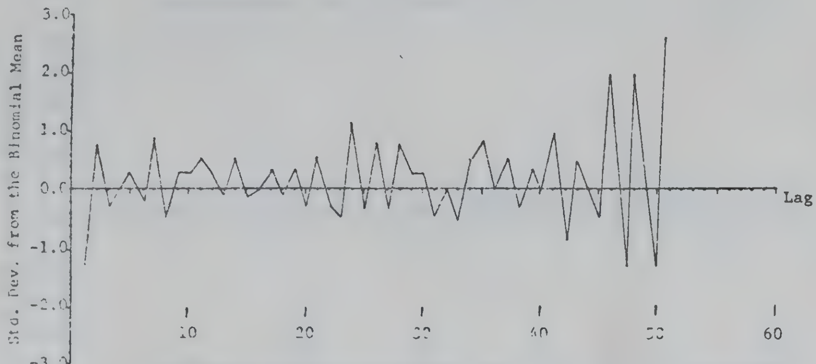
Autoassociation Plot for Interval 3562 - 3864 for 9 Lithotypes



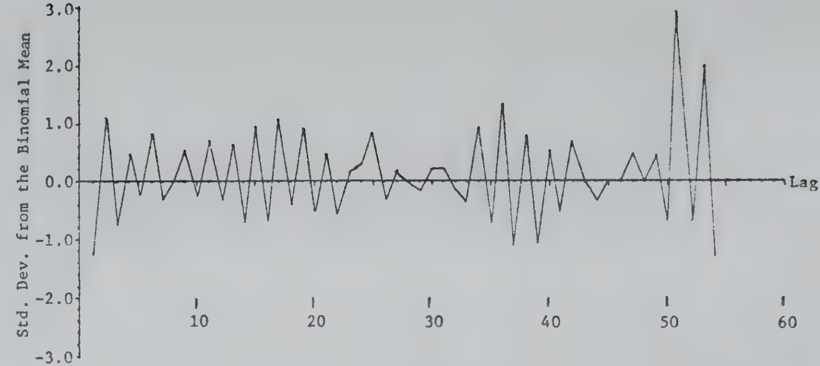
Autoassociation Plot for Interval 0 - 420 for 6 Lithotypes



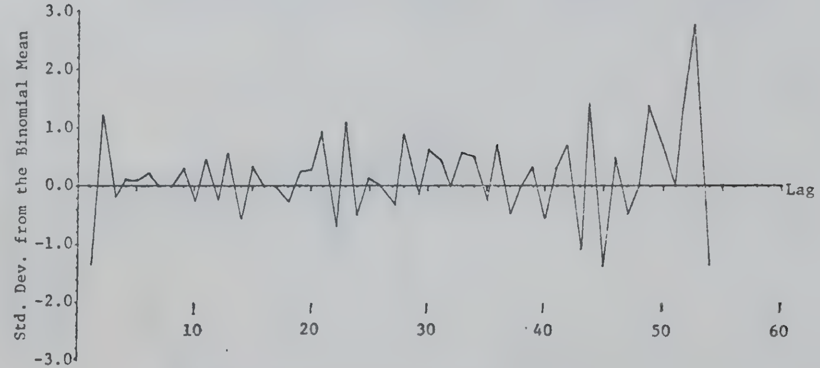
Autoassociation Plot for Interval 420 - 806 for 6 Lithotypes



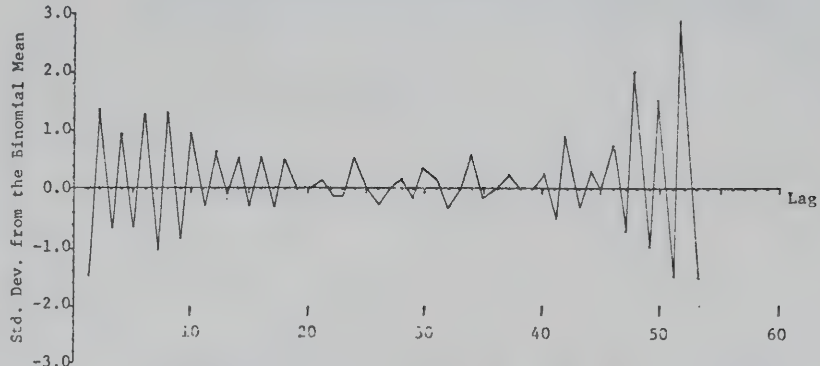
Autoassociation Plot for Interval 806 - 1188 for 6 Lithotypes



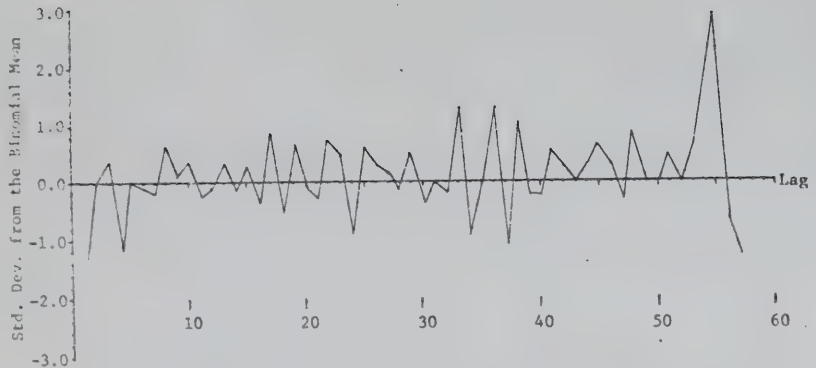
Autoassociation Plot for Interval 1188 - 1482 for 6 Lithotypes



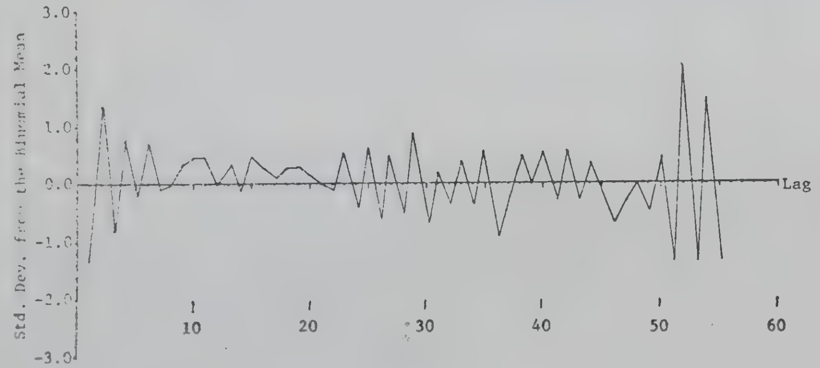
Autoassociation Plot for Interval 1482 - 1830 for 6 Lithotypes



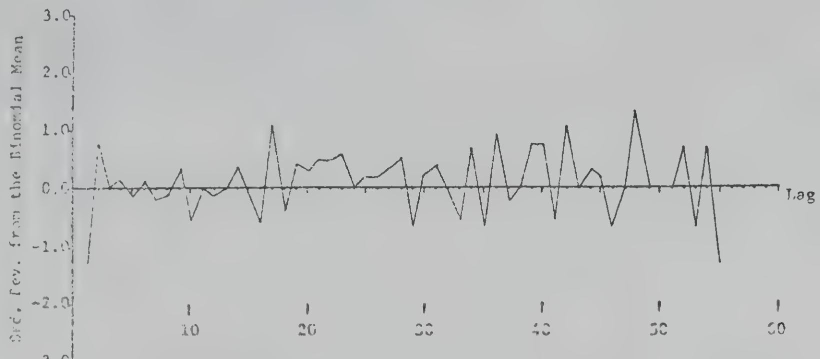
Autoassociation Plot for Interval 1830 - 2134 for 6 Lithotypes



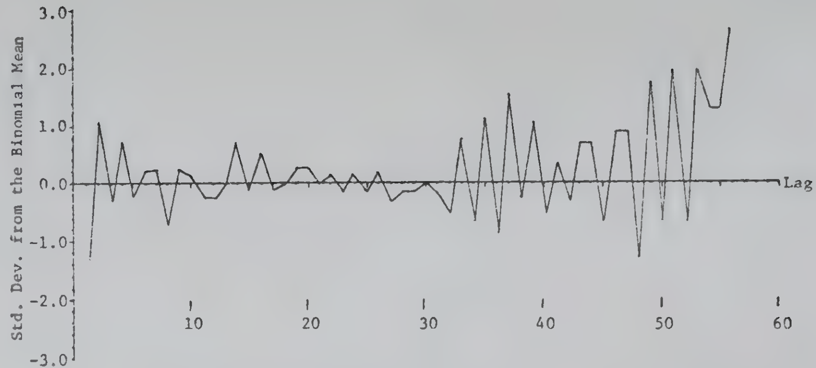
Autoassociation Plot for Interval 2134 - 2430 for 6 Lithotypes



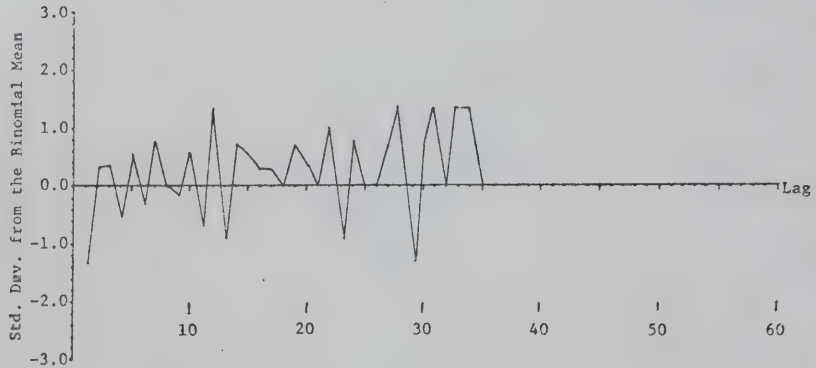
Autoassociation Plot for Interval 2430 - 2962 for 6 Lithotypes



Autoassociation Plot for Interval 2762 - 3168 for 6 Lithotypes



Autoassociation Plot for Interval 3168 - 3562 for 6 Lithotypes



Autoassociation Plot for Interval 3562 - 3864 for 6 Lithotypes

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